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COLLEGE OF AGRICULTURE,

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CONTENTS.

All communications relating to this Journal should be addressed to the Director of the College of Agriculture.

A Genetico-Physiological Study on the Formation of Anthocyanin and Brown Pigments in Plants.

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With Plate I and two Text-figures.

CONTENTS

Introduction.

The workers in genetics have established the fact that in certain cases the formation of anthocyanin pigments is caused by the interaction of a number of definite pigment yielding components which are retained by the separate genetic factors. Neither of these components has the power to produce the pigment unless the complete system is established by their union. We owe much to the labours of BATESON, PUNNETT, Miss SAUNDERS, Miss WHELDALE, Baur and many others on the part of genetics,[1] and WILLSTÄTTER and his collaborators in the field of chemistry who have shown for the first time, the exact chemical constitution and the interrelationship of the colouring matters[2] concerned.

The present paper deals with the result of an investigation carried out in order to discover what relation exists between anthocyanin and brown pigments both of which occur widely in the plant kingdom and what observation can be made with regard to the physiological action of the genes which are analysed by the breeding experiments for the characters in which those pigments are concerned.

I.   Physiological Study.

1.   THE ACTION OF OXIDIZING ENZYMES ON ANTHOCYANINS.

If we accept the view that anthocyanins are formed by the oxidation of flavone instead of by reduction, and the oxidizing enzymes play an essential part in this change in the living plant cells, it is necessary to offer the direct evidence to lend support to the view.

When an alcoholic or aqueous extract of anthocyanin which is slightly

1. See WHELDALE, M., Anthocyanin Pigments of Plants. 1916.
2. See PERKIN, G. A., and EVEREST. A. E., The Natural Organic Colouring Matters. 1918.

acidified to check the formation of the colourless isomer, is mixed with the solution containing active oxidizing enzymes, the characteristic red colour diminishes gradually and finally becomes pale yellow or practically colourless. The aqueous solutions of hydrogen peroxide and certain other inorganic oxidizing agents have the same effect as the enzyme. Such phenomena have been observed by BOUFFARD (1902), KASTLE (1905), KASTLE and HADEN (1911), COMBES (1913), ATKINS (1916) and NAGAI (1917).[1]

The reversible change of flavone to the coloured substance of anthocyanin-like nature by means of reducing and oxidizing agents respectively has been observed by many. ALLEN (1901)[2] stated that when an acidified (by hydrochloric acid) alcoholic solution of quercetin was treated with sodium amalgam the liquid assumed a fine purple colour and on concentration yielded red prisms which dissolved in alcohol and a little alkali forming a green solution, the solution being readily reoxidized with formation of quercetin on exposure to the air. COMBES (1913)[3] observed a similar reversible change in the yellow pigment isolated from the leaf of *Ampelopsis hederacea*.

In the study of anthocyanin in the corn flower, WILLSATÄTTER and EVEREST (1913)[4] found that when an alcoholic solution of cyanidin was warmed with dilute hydrogen peroxide solution, the colour diminished. When it was again warmed on the water bath with the addition of a few drops of dilute hydrochloric acid, the liquid became yellow, and by extracting with ether, beautiful bright yellow crystals were obtained which when treated with alkalies, yielded a deep yellow solution. Miss WHELDALE (1914)[5] attempted

1. BOUFFARD, A., Action de l'acid sulfureux sur l'oxydase et sur la matière colorante du vin rouge. Comp. Rend. Acad. Sci. Paris. 134 : 1380, 1902. KASTLE, J. H., A Method for the Determination of the Affinities of the Acids Colorimetrically by Means of Certain Vegetable Coloring Matters. Am. Chem. Jour. 33 : 46, 1905. KASTLE, J. H. and HADEN, R. L., On the Color Changes Occurring in the Blue Flowers of the Wild Chicory, Cichorium intybus. Am. Chem. Jour. 36 : 315, 1911. COMBES, R, Passage d'un pigment anthocyanique extrait des feuilles rouges d'automne un pigment jaune contenu dans les feuilles vertes de la meme plante. Comp. Rend. Acad Sci. Paris, 152 : 1454, 1913. ATKINS, W. R. G., Recent Researches in Plant Physiology. 1916. NAGAI, I, The Action of Oxidase on Anthocyanin. Bot. Mag. Tokyo, 31 : 65, 1917.

2. ALLEN, A. F., Commercial Organic Analysis. Vol. III, Part 1, 440, 1901.

3. COMBES, loc. cit

4. WILLSTÄTTER, R and EVEREST, A. E, Ueber den Farbstoff der Kornblume. Liebig. Ann. 401 : 189, 1913.

5. WHELDALE, M, Our Present Knowledge of the Chemistry of the Mendelian Factors for Flower Colour. Jour Genet. 4 ; 109, 1914.

to obtain the flavone from the anthocyanin of *Antirrhinum* by the same manner just quoted, but failed. She obtained only a yellowish brown solution.

HARROW and GIES (1919)[1] observed the reversible colour changes in the solution of flavone and anthocyanin isolated from the flower of tulips by means of nascent hydrogen and hydrogen peroxide respectively.

The writer observed that the coloured reduction product of quercetin, myricetin, apigenin, and luteolin yielded a yellow solution when treated with hydrogen peroxide and in the case of the first two, the original colours were resumed by further reduction by means of hydrochloric acid and magnesium powder. If, however, the reduced, coloured solutions were decolourized by an excess of hydrogen peroxide, the yellow solution so obtained failed to recover the reddish hue by reduction.

The aqueous extract of the violet anthocyanin from the perigone leaf of *Iris Kæmpferi* and the purple one from the leaf of *Perilla nankinensis* were also changed to yellow by hydrogen peroxide and they yielded again an orange red colour by reduction but no initial bluish hue.

The red colour of the reduced solution of quercetin, quercitrin, and myricetin were converted to yellow by the addition of an aqueous solution of potassium permanganate, and the further addition finally rendered the solution completely colourless.

The mode of action of hydrogen peroxide and the oxidizing enzyme on anthocyanin was studied colorimetrically. One of the difficulties here met with, was the change in hue as the action proceeded. It is naturally to be expected that yellow colour should increase in depth as the anthocyanin is converted to a flavone like substance and at the point where fifty per cent of anthocyanin is converted to the yellow substance, the colour of the solution becomes about half way between red and yellow, namely orange. When violet anthocyanin is used, the change in hue is so distinct that no direct comparison can be made with the standard colour. With red and orange-red ones, however, the change in hue does not take place in a marked degree up to a certain point, hence the approximate measurement becomes possible.

    1. HARROW, B. and GIES, W. J., Experimental Studies on Plant Pigments. Columbia Univ. Proc. Soc. Exp. Biol. Med. 16 : 8, 1918, Review in, Chem. Abstract. 13 : 2695, 1919.

To illustrate, the following results will be mentioned. Ten grams of the fresh petals of scarlet *Papaver Rhoeas*[1] were extracted with 150 cc of distilled water. The colour of the extract was deep red. This was taken as 100, and 50, 25, and 12.5 per cent solutions were prepared. The peroxidase used was prepared from the pressed sap of hypocotyls and rootlets of the soy bean seedlings by precipitating with alcohol. Five cc of the enzyme solution was added to fifty cc of a dilute hydrogen peroxide solution (0.1 cc corresponded to about 0.0003 g oxygen). The mixtures were put in large test tubes of the diameter 4 cm and they were kept in the water bath. The temperature was kept between 17.0 and 17.5 C. At different intervals of time, five cc of the mixture were pipetted out into a test tube and one cc of concentrated hydrochloric acid was added to stop the enzyme activity and to deepen the colour. The standard solution was prepared in the same manner immediately after the enzyme was added. Each portion was then compared with the standard solution so prepared by Dubosq's colorimeter and the intensity of colour of the different portions was expressed as percentages of the initial colour which was taken as 100.[2] They gave the following result.

TABLE 1.

Decolorization of anthocyanin by peroxidase.

A.   Relative strength of anthocyanin = 100

B.   „   „   „   „   = 50.0

C.   „   „   „   „   = 25.0

D.   „   „   „   „   = 12.5

A.

Time in minutes (t)	Intensity of colour (a − x)	k
0	100.0	0
7.0	100.0	0
40.0	99.06	0.00024
63.5	93.75	0.00102

1. According to WILLSTÄTTER and WEIL (LIEBIG. Ann. 412 : 231, 1916.) one of the pigments of a double purple-scarlet variety is mekocyanin which is a diglucoside of cyanidin.

2. The initial colour corresponded with somewhere between Peach red to Scarlet in RIDGWAY'S Color Standard.

B.

Time in minutes (t)	Intensity of colour (a − x)	k
0	100.0	0
6.5	97.50	0.00491
15.0	90.00	0.00679
39.0	75.00	0.00738

C.

0	100.0	0
6.0	93.75	0.01075
15.0	76.88	0.01752
26.5	62.50	0.01773
48.0	56.25	0.01277
62.0	53.12	0.01027

D.

0	100.0	0
5.0	81.25	0.04154
14.0	62.50	0.03323
18.5	55.00	0.03233
36.0	50.00	0.02666
39.5	46.25	0.02535
44.5	43.75	0.01992

The figures in the third column are the values of the velocity constant calculated as unimolecular reaction, $k = \frac{1}{t} \log. \frac{a}{a-x}$. They show that the rate of decomposition in A was very slow owing to the relative high concentration of anthocyanin and the value of k increased as the reaction advanced. In B, a similar tendency was observed but in D, the value of k rapidly decreased as the reaction advanced. Since the strength of the enzyme was the same in all cases, the different values obtained indicate that the mode of action of peroxidase differed by the relation of the initial concentration of the enzyme to the substrate.

If the values of $a − x$ in A are plotted against time, they show nearly a
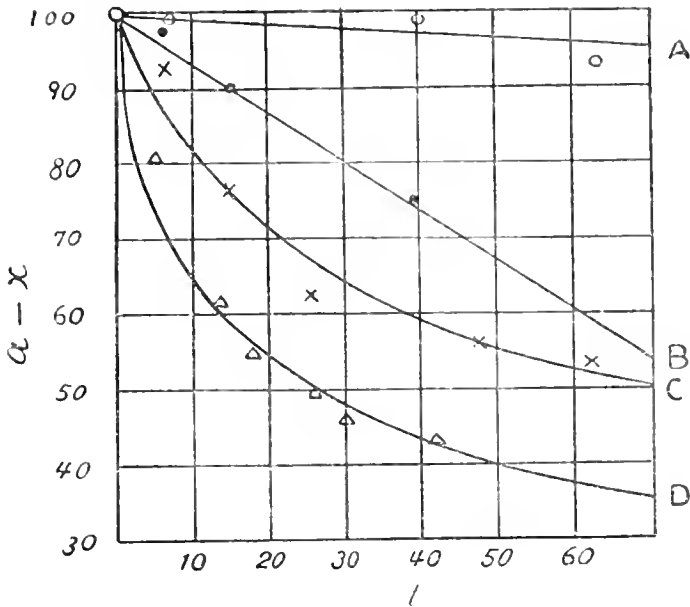
Text-fig. 1. Graphs showing the decomposition of anthocyanin
by peroxidase. See Table 1.

straight line suggesting that the rate of decomposition was approximately
proportional to the time of reaction, hence the value of k calculated for the
unimolecular reaction increased as time advanced. If, however, the value of
log. $a-x$ are plotted against time, the curves of B, C, and D do not form
straight lines, while the values of log. $a-x$ are plotted against log. time, the
curves show more nearly the straight lines. This seems to show that the
value of the enzyme was not constant. The active portion of the enzyme de-
composed as the reaction proceeded. Two reactions, the decomposition of the
enzyme itself and that of anthocyanin by the active portion of the enzyme in
the system seem to go on simultaneously, so that the rate of decomposition
of the latter cannot be regarded as a simple uni-molecular reaction. The
reaction may be uni-molecular only when the specific ratio of the enzyme to
the substrate in held and in which the rate of decomposition of the enzyme
may be so slow that its value can be considered as nearly constant, while the
decomposition of the substance goes on with the constant rate. Hence we are
able to consider the value of $a-x$ as the function of time.

Similar observation was made with laccase. Ten cc of a 0.6 per cent

laccase solution[1] which gave the direct oxidase reaction by phenylendiamine, alpha naphtol, and guaiacum were added to fifty cc of the anthocyanin extract which was prepared from the dried powder of the flower of *Lilium tigrinum* by extraction with dilute alcohol. The mixture was kept at the room temperature which varied from 19.0 to 20.0 C.

TABLE 2.

Decolorization of anthocyanin by laccase.

Time in minutes (t)	Intensity of colour (a−x)	k
0	100.00	0
12	90.63	0.00820
30	83.75	0.00592
50	73.12	0.00626
74	67.00	0.00533
101	62.50	0.00465
201	42.50	0.00419

TABLE 3.

Same as Table 2, except the concentration of the enzyme which was reduced to half that of the former.

Time in minutes (t)	Intensity of colour (a−x)	k
0	100.00	0
2	97.31	0.00094
20	90.77	0.00198
32	84.27	0.00258
100	76.92	0.00262

It was found that certain salts and the sugars retarded the activity of the enzyme. One of the experiments gave the following result. Fifty cc of a weak alcoholic (25 per cent) extract of anthocyanin from the violet coloured perigone of *Iris Kæmpferi* to which was added glucose (MERCK's pure) to

1. The material was kindly furnished to the writer by Prof. K. SHIBATA.

make up 5 per cent, was mixed with 0.2 cc of a dilute hydrogen peroxide and 0.5 cc of the enzyme solution which was prepared from the pressed juice of the soy bean seedling twice precipitated by alcohol. The mixture was kept at 19.0 to 20.0 C. The change in the hue from violet to red was observed as already mentioned but by an addition of strong acid to the pipetted portion by which the comparison of the colour was made, the colour was red all alike. Thus:

TABLE 4.

Influence of glucose on the decolorization of anthocyanin by peroxidase.

5 per cent glucose			Control (without glucose)			
Time (t)	Intensity of colour (a − x)	k	k	Time (t)	Intensity of colour (a − x)	k
0	100.00	0	0	100.00	0	
10	97.64	0.00239	10	90 18	0.09999	
20	95 21	0.00214	20	83.81	0.09884	
32	90.48	0.00313	40	78 09	0.00589	
62	88.57	0.00175	69	76.19	0.00396	

The above fact seems to bear some physiological importance. The higher the concentration of sugar or salts dissolved in the cell sap, the weaker would be the action of oxidizing enzyme on anthocyanin. Thus the latter may be protected from decomposition.

As already mentioned, hydrogen peroxide alone decolorizes the anthocyanin and if a small amount of finely pulverized animal charcoal is added, the action of hydrogen peroxide is highly accelerated.

The different amount of animal charcoal and 1 c.c. of hydrogen peroxide which was equivalent to 0.014 g. oxygen was added to 5 c.c. of a reduced alcoholic solution of 0.001 mol. quercitrin. Time required for the mixtures to be completely decolorized at 14.0 C.—16.5 C. was as follows:

I. NAGAI :

TABLE 5.

Influence of animal charcoal on the decolorization of
anthocyanin by hydrogen peroxide.

Charcoal added in gram. (q)	No. of minutes required for decolorization (t)	q'
0.05	29.0	1.45
0.04	34.5	1.38
0.03	42.0	1.26
0.02	62.0	1.24
0.015	89.0	1.34
0.01	140.0	1.40
Control	ca. 400.0	— —

When the concentration of hydrogen peroxide varied and the amount of
animal charcoal made constant, at the temperature 20.0 C. the following result
was obtained.

TABLE 6.

Same as Table 5.

Charcoal added in gram	Cc of hydrogen peroxide added	Concentration equivalent to oxygen in g.	No. of minutes required for decolor.
0.05	1	1 = 0.011	6.0
0.05	1	1·2	11.5
0.05	1	1·4	18.5
0.05	1	1·8	20.5
0	1	1 = 0.011	ca. 180.0

It seems clear, from the data so far presented, that although the oxidizing
enzymes, are universally present in the plant cell, particularly co-existing with
anthocyanin, and although the normal oxygen relation is essential to the
formation of anthocyanin in the living tissue as we shall see later, yet these
enzymes have no direct relation to the formation of anthocyanin from flavone.
On the contrary, anthocyanin is converted to a flavone-like yellow substance
by the action of the oxidizing enzymes.

2.   The Action of Oxidizing Enzymes on Flavones.[1]

When the aqueous or alcoholic extracts of the plant tissues which are rich in flavone, are mixed with the freshly prepared pressed plant-juice containing the active oxidase, a marked brown to reddish brown colour is formed instantly. The more flavone the extract contains, the deeper is the colour produced. On standing, a brownish precipitate is formed and subsides. The production of that colouring matter is produced at the expense of the flavone contained in the extract. It can be proved by testing the intensity of the reduction colour of the extract at the beginning and at the end of the experiment. At the end of the experiment, a marked decrease in the flavone content can be seen by means of its reduction colour, whenever the brown colouring matter is formed.

The extract of leaves, twigs, white flowers, fruits, and other parts of plants of different species were examined and in general, the parallelism in the depth of the brownish colour produced by the oxidase and that of the reduction colour of the extract was established. The brownish colouring matter thus formed has its colour intensified by the addition of alkali and, on the addition of acid diminishes or changes to yellow. The colour change just mentioned is very sensitive being performed in an indicator like manner.

Pure chemical preparations were then tried and it was found that certain flavones and flavonols yielded a marked oxidation colour by the action of oxidizing enzymes. For example, myricetin, even in a comparatively dilute alcoholic solution, yielded a beautiful red colour immediately after the oxidase was added. The colour, however, was unstable, and changed to brownish red and finally to brown. Quercetin and luteolin yielded also a deep red colour rapidly changing to brown. Kæmperol, apigenin, and tringin on the other hand, showed practically no change. In the former cases, the reduction colour when tested after being acted on by the enzyme, was decidedly less deep than that of the control or that of the initial one, while in the latter cases, practically no difference was observed showing that the flavones remained unchanged.

Glucosides gave less characteristic colour than non glucosides. Myricitrin

1.   The full account of the investigation will be published by the author jointly with Prof. K. Shibata.

and quercitrin yielded a less bright red colour than did myricetin and quercetin respectively.

These observations indicate that the oxidation colours of flavones and flavonols are largely influenced by the chemical constitution of the substance especially the number and the position of OH group substituted in beta phenyl group as in the case of the reduction colours.

It is now beyond bonbt that the action of oxidases and peroxidases on flavones bears no direct relation to the chemical changes of flavones to anthocyanins; nevertheless the oxidizing enzymes may play an important part in other metabolic changes in the living tissue.

3.   Flavone Derivative as Chromogenic Substances of Reddish Brown Plant Pigments (Phlobaphenes).[1]

The reddish brown and brown pigments are widely distributed in the plant kingdom, namely in the bark, rhizome, seed coat, dead leaves and in others, some of them are known as phlobaphenes which were originally the name given by Stähelin and Hofstetter (1814)[2] to certain brownish red substances of unknown chemical constitution isolated from the bark of *Pinus sylvestris*, *Platanus acerifolia*, *Betula alba*, *Cinchona Calisaya* etc.   According to these authors and others,[3] phlobaphenes are considered to be the oxidation product of tannins.   Hlasiwetz considered that there are two groups of substances which may respectively give rise to two groups of phlobaphenes.   One of the groups of phlobaphenes to which 'china red', 'chinava red', and 'oak red' etc. belong, yields by fusion with alkali, protocatechuic acid alone, and the other group to which 'filix red', 'ratanhia red' and 'chestnut red' belong, yields together with protocatechuic acid, phloroglucin.   Along with them,

1. Nagai, I., On some Reddish Brown Plant-Pigments. Bot. Mag. Tokyo, 31 : 1, 1917. In Japanese.

2. Stähelin, C. and Hofstetter, J., Chemische Untersuchungen einiger Rinden. Liebig. Ann   51 : 63, 1844.

3. Hesse, O., Ueber die humusartingen Bestandtheile der China-rinden. Liebig. Ann. 109 : 341, 1859. Hlasiwetz, H., Ueber die Beziehungen der Gerbsäure, Glucoside, Phlobaphene und Harze. Liebig. Ann. 113 : 209, 1867. Niebenstein, M., Beitrag zur Kenntnis der Gerbstoffe II. Berich. d.d. chem. Gesel. 42 : 353, 1909. See also Perein, A. G. and Everest, A. E., Loc. cit. page 436 et seq.

a group of substances such as maclurin, luteolin, catechin, quercetin and scoparin, also yields protocatechuic acid and phloroglucin as their decomposition products. So he supposed that those phlobaphenes which yield protocatechuic acid and phloroglucin are the derivatives of the substance just mentioned. In the epidermis of leaves and the periphery of the bark, those substances may undergo oxidation by the contact with air resulting in the formation of phlobaphene.

WALTER (1890)[1] studied the sklerotic tissue of the rhizome of ferns and came to the conclusion that the brown pigment deposited in the membrane is identical with phlobaphene and its physiological function was considered by him to be the protection of the tissue from the injurious effect of the humidity of the substrate under which these plants grow.

Some of the brown pigments found in nature are hardly soluble in common organic solvents like ether, alcohol, benzine, and acetic ether, but are readily soluble in water and especially in alkaline solutions, yielding a deep brownish red to wine red colour, which by acid is instantly changed to yellow. The brown and reddish brown oxidation products of flavones and flavonols as already stated in the preceding chapter, possess similar properties. Since the flavone derivatives are widely distributed in plants, it seems quite probable to assume that some of them give rise to phlobaphene by oxidation as HLASIWETZ has already supposed. Therefore, we may regard certain flavone and flavonol derivatives as the chromogen of both anthocyanin and phlobaphene pigments.

We assume that certain relations existing among these pigments may be somewhat as follows:

Chromogenic substance	Initial change	Subsequent changes	Product
Certain flavones flavonols and their glucosides	reduction	formation of complex with salts [2]	anthocyanins of different hues.
	oxidation	condensation & polymerization	phlobaphenes

1. WALTER, G., Ueber die braunwandigen sklerotischen Gewebeelemente der Farne, mit besonderer Berücksichtigung der sog. "Stützbündel" Russow's. Bibliotheca Botanica. Heft 18 : 21, 1890.

2. See SHIBATA, K., SHIBATA, Y. and KASHIWAGI, I., Studies on Anthocyanins. Color Variation in Anthocyanins. Jour, Amer. Chem. Soc. 41 : 208, 1919.

4. Role of Oxygen in the Development of the Chromogenic Substance and Anthocyanin.

It is already known that the formation of anthocyanin is suppressed when the normal oxygen relation is artificially checked in the living plant.[1]

The writer observed that the hypocotyls of the seedling of the buckwheat remained white as long as they were kept in the dark, but when exposed to the day light, a deep red colour developed. If they were kept in the glass chamber in which the air was replaced by hydrogen gas, they did not form the pigment even when exposed to the day light. The chromogenic substance could be detected from the colourless samples. The alcoholic extract gave a distinct red colour by reduction by means of hydrochloric acid and magnesium powder.[2]

The young seedlings of certain varieties of soy bean form a deep purple anthocyanin pigment together with chlorophyll in the elongated hypocotyls a few days after germination, if they are exposed to strong sun light. If, however, the normal supply of air is checked, the pigment does not develop as in the case with the buckwheat. The following experiment shows clearly the above relation. The young seedlings of a variety of yellow cotyledon which were devoid of both pigments, were placed under the following conditions:

Lot A. A small, tightly fitted glass chamber in which the air was replaced by hydrogen gas which was generated by Kipp's apparatus and washed by the solution of potassium permanganate once. The chamber was dipped in water.

Lot B. Same as A, but the chamber was kept in the air.

Lot C. The chamber was simply closed up.

Lot D. The chamber opened, as control.

All the chambers were kept in a glass case which was placed near the

1. EMERY, M., Sur les variations de l' eau dans les perianthes. Bull. Soc. Bot. France. 36 : 322, 1889. KATIC, D. L., Beitrag zur Kenntnis der Bildung des roten Farbstoffs (Anthocyan) in vegetativen Organen der Phanerogamen. Inaug. Dissert., Halle. 1905. Cited in WHELDALE, M., Anthocyanin Pigments of Plants. 1916.

2. See also MIEGE. E., Recherches sur les principales espèces de Fagopyrum. Thèse de Doctorat de l, Univ. Paris. 1910. Cited in COMBES, B., Recherches biochemiques experimentales sur le rôle physiologique des glucosides chez les végétaux. Rev. General. d. Bot. 30 : 89, 1918.

window to receive direct sunlight. Three days after the experiment was set up, chlorophyll developed in the seedlings in *C* and *D*; the deep purple pigment was also formed in the latter. None of the pigment were formed in *A*. On fourth day, a slight purple colour was observed in *C* but in *A* and *B*, it failed to appear. In the same day, the chamber *B* was opened to allow normal air. Two days later (on the sixth day) the seedlings in *A* remained still without the pigment. In *B*, chlorophyll was found in the cotyledons but no purple pigment in the shoots. In *C*, the development of the purple pigment was still feeble, whereas in *D* (control), all the seedlings were deeply coloured.

It is a well known fact that the leaf scale of the onion bulb becomes yellow on exposure to light. It is chiefly due to the formation of quercetin.[1] If, however, the bulbs of which already coloured scales were removed, were kept in the closed chamber filled with hydrogen gas, the formation of flavone was inhibited. The bulbs were cut in halves and the coloured scales were removed. The halves were kept in the closed glass chamber in which the air was replaced by hydrogen gas and the other halves were kept for the control experiment. They were kept for sixteen days during which the gas was renewed once. Neither yellow nor green pigment was found except in the control specimens. When the chambers were opened, the bulbs were turgid, but became soft immediately after the air was let in. An equal weight of the scales was taken from the treated and control samples and extraction was made with equal volumes of a weak alcohol. The extracts so prepared, were reduced by means of hydrochloric acid and magnesium powder in the usual manner. They gave the following flavone reactions :

Treated   Trace of pink colour.
Control   Red.

It showed that normal air is essential to the development of flavone in the leaf scale of the bulb of onion even when light is amply supplied.

The bulbs of *Allium Ledebourianum*, a common weed in certain parts of Japan, are white when they are grown in the ground, but they are dug out

1. PERKIN, A. G. and HUMMEL, J. J., Occurrence of Quercetin in the Outer Skin of the Bulb of the Onion (Allium cepa). Chem. Soc. Trans. 69 : 1295, 1896.

and exposed to day light, a deep violet-red colour develops. The coloured
scales were removed and the white portions were kept in the same manner
as in the previous experiment with the common onion bulbs. No red pigment
was formed during the experiment which lasted for two weeks. The bulbs in
the control became deep green and the treated ones were white. Alcoholic
extracts were prepared, and the flavone content was examined. They showed :

Treated	No reaction
Control	Trace of pink colour

Here the flavone was formed in extremely slight amount even when the
light and the air relation was normal.

5. A GROUP OF SUBSTANCES OF UNKNOWN CHEMICAL NATURE
AS THE CHROMOGEN OF ANTHOCYANINS AND
REDDISH BROWN PIGMENTS.

A body of evidences accumulated by the different investigators show[1] that
a group of chromogenic substance is present in plants which gives rise to
anthocyanin-like pigments as well as the brown pigments.

WOLFF and ROUCHERMANN (1915)[2] observed the presence of a chromogenic
substance in a number of plants which are sensitive to the action of laccase
yielding the brown pigment. The phenomena observed in iodine colour tests
are always preceded by the action of a laccase. The authors considered that
the chromogens are of the same kind in different plants and the brown
pigments which are formed in various plants or organs might be regarded as
products of oxidation. SHIBATA[3] obtained the chromogenic substance from a

1. MALVEZIN, PH., Sur 1 'origine de la colour des raisins rouges. Comp. Rend. Acad. Sci.
Paris. 147 : 318, 1908 ; LABORDE, J., Sur 1 'origine de la matière colorante des raisins rouges et
autres organes végétaux. Ibid. 116 : 1411, 1908 ; DEZANI, S., Le sostanze cromogene dell' uva
bianca. Staz. sper. agr. ital., Modena. 43 : 328, 1910 (cited in Atkins, W. R. G., Researches in
Plant Physiology. 1916) (also in Jour. Chem. Soc., Abstract 100 : 223, 1911.) ; KEEGAN, P. Q., The
Chemistry of the Flower Pigments. Chem. News. 107 : 181, 1913 ; TSWETT. M., Zur Kenntnis des
vegetabilischen Chamaeleons. Ber. d. d. bot. Gesell, 32 : 61, 1911 ; TSWETT. M., Beiträge zur
Kenntnis der Anthocyane. Ueber künstliches Anthocyan. Bioch. Zeit. 58 : 225, 1913.

2. WOLFF, J. and ROUCHERMANN, N., Sur les propriétés d'un chromogène universellement
répandu dans les végétaux. Comp. Rend. Acad. Sci. Paris. 161 : 399, 1915 ; WOLFF, J., Phénomènes
d' oxidation et de réduction portant sur les chromogènes des végétaux. Ibid. 160 : 716, 1915.

3. SHIBATA, K., Bot. Mag. Tokyo. 31 : 1919. A brief note in Japanese.

number of plants which yielded a deep red colour on heating with hydrochloric acid and with oxidase a brown to reddish colour. The red colouring matter obtained by heating with the acid is changed to blue by an alkali like anthocyanin. The chromogenic substance is soluble in alcohol and in ether, and with ammonia yields a deep yellow colour as observed with flavone but by reduction yields no colour. It is very sensitive to the action of oxidases forming a brown substance of which the colour is intensified by alkali and changed to yellow or yellowish brown by acid. The plant extract which contains both this substance and certain kinds of flavones shows a characteristic red colour by reduction as well as when heated with hydrochloric acid. Shibata considered that the substance might be regarded as a colourless anthocyanin. Moreaux (1914)[1] considered it proper to rank along with red, violet and blue pigments designed as anthocyanins, the colourless compounds which are inseparable from them and which are always found in the cells as earlier or later products, being closely related to them as regards chemical composition and as having in common with them a mitochondrial origin.

We do not know as yet the chemical nature of the substance in question but the similarity in certain properties exhibited by the extract from a number of plants, suggests that a closely allied substance may be present widely in the plant kingdom and it may give rise to certain anthocyanins and the reddish brown pigments. The bearing of the fact on genetics is hardly to be overlooked, for we are now able to locate and to approximate the chromogen in the part of a plant by the test for flavone and the substance under discussion. In the following pages, the former will be named, for the sake of convenience, chromogenic substance F, and the latter chromogenic substance P.

A number of species of plants especially the cultivated plants, were examined for these chromogenic substance. The method employed was as follows. To each gram of the fresh material, ten cc of a weak alcohol were added and extracted on the water bath. Usually three to five grams of the materials were taken. Five cc of the extracts were reduced with one cc of concentrated hydrochloric acid and magnesium powder for the chromogenic substance F, and another five cc were simply boiled with the acid which was

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1. Moreaux, F., L' origine et les transformations des produits anthocyaniques. Bull. d l oc. Bot. France. 61 : 390, 1914.

added in the same proportion as before, for the chromogenic substance P.
After the treated extracts were cool, the colours of the extracts were compared
with those of the standard colours and recorded. The standard colours were
prepared in the following manner.

Twenty five cc of quercetin dissolved in absolute alcohol, were reduced
with five cc of concentrated hydrochloric acid and about 0.5 grams of magnesium
powder.

Colour scale	Concentration of quercetin
I	I : 1,000
II	I : 2,000
III	I : 3,000
IV	I : 5,000
V	I : 10,000
VI	I : 20,000

Thus the relative value of the chromogen content in the material was
approximately determined. The result of a survey established the following
fact.

The chromogenic substance P can be detected in different parts of plants,
i.e., the leaf, stem, shoot, rhizome, bark, wood, white petals, perigone, seed
coat, mesocarp, stigma etc.

It occurs quite independently or in company with the chromogenic sub-
stance F. Even in the same plant, the distribution of the two chromogens is
quite distinct in different organs.

Light seems to have no direct relation to the distribution of the chromo-
genic substance P unlike the case of the chromogenic substance F (flavones).[1]
For, the underground parts and the interior portions of the upper ground
tissues of many plants contain a considerable amount of the chromogenic
substance P. The bark of young twigs, the seed of immature seeds which
ultimately become brown, red or black when fully mature, the young fruits
and berries of many of the cultivated fruit trees are especially rich in the
chromogenic substance P. Thus, for example :

1.   SHIBATA, K. NAGAI, I. and KISHIDA, M , The Occurrence and Physiological Significance of
Flavone Derivatives in Plants. Jour. Biol. Chem. 28 : 93, 1916.

TABLE 7.

Chromogen content of the plant extracts.

Name of plant	Part examined	Relative value of chromogens P	F
Cryptomeria japonica	Green leaf	I	IV
„ „	Green bark	I — — + I	IV +
„ „	Wood & pith (young twig)	IV	+
Ficus parvifolia	Green leaf	I +	V
„ „	Bark	I	V
Platanus occidentalis	Bark	I + + +	IV —
„ „	Wood	IV	—
Aesculus turbinata	Bark	I +	+
„ „	Wood	IV	—

In the immature green seed of different legumes, the chromogen can readily be detected, so that it is possible to predict whether the seeds may be coloured or not in adult condition. So far the writer has found, the colourless or white seeds show practically no chromogen reaction when they are still young, the relation of the pigment to the chromogen being quite well marked.

TABLE 8.

Chromogen content of the extracts of green seed of the leguminous plants.

Name of plant	Part examined	Colour of seed when ripe	Relative value of chromogens P	F
Indigofera pseudotinctoria	Seed	Brown	I	—
Vicia sativa	„	„	II +	—
Pisum sativum	„	„	I +	+
Phaseolus vulgaris	„			
" Kotenashi "	„	White	—	—
" Ohtenashi "	„	„	—	—
" Kianeko "	„	Yellow pied	IV	+

1.   + sign denotes the deeper colour than that of the colour scale stated. The sign alone denotes the trace of colour or below VI

Name of plant	Part examined	Colour of seed when ripe	Relative value of chromogens	
			P	F
" Golden Wax "	Seed	Black	I –	+
" Closen "	,,	Reddish brown	II	–
" Longfellow "	,,	Brown mottled on light yellow	II	+
" Kumamoto-Ingen "	,,	White	–	–
" Black Valentine "	,,	Black	II	–
" Canadian Wonder "	,,	Reddish brown	II	–
" Birma-Ingen "	,,	Black mottled on brown	I –	–
Phaseolus radiatus var. *aureus*				
Unnamed	,,	White (pale buff)	–	–
" Shiro-Adzuki "	,,	,,	–	–
Unnamed	,,	buff	I –	( ) [1]
,,	,,	Red	I –	IV
" Maru-Ba "	,,	,,	I –	IV
" Wase-Dainagon "	,,	,,	I –	IV
" Madara "	,,	Black flecks on red	I	IV
" Kensaki "	,,	Red	I	IV
" Yogore "	,,	Dark flecks on buff	II	+
" Midori "	,,	Greenish grey	I	( )
" Wase-Otsubu "	,,	Dark red	I	IV

As we have just seen, the chromogenic substance P is plentifully found in the extracts of the immature coloured seed of *Phaseolus vulgaris*, but very scarce in or nearly devoid of the chromogenic substance F. In the leaf, the reverse is the case.

TABLE 9.

Chromogen content of the leaf of *Phaseolus vulgaris*.

Name of variety	Colour of flower	Colour of leaf	Chromogen	
			P	F
" Kotenashi "	White	Yellowish green	–	–
" Ohtenashi "	,,	,,	–	II
" Kinneko "	Cream	,,	–	IV

1 Orange colour

Name of variety	Colour of flower	Colour of leaf	Chromogen	
			P	F
"Golden Wax"	Pale pink	Greenish yellow	+	IV
"Chosen"	,,	Green	—	III
"Longyellow"	White	,,	—	III
"Kumamoto-Ingen"	Cream	,,	—	IV
"Black Valentine"	Pale pink	,,	+	IV
"Canadian Wonder"	Pink	Greenish yellow	—	III
"Biruma-Ingen"	,,	,,	—	III

Unlike the case of the above, both chromogenic substances co-exist in the leaf of certain fruit trees.

TABLE 10.

Chromogen content of the leaf of certain fruit trees.

Name of plant	Chromogen P	Chromogen F
Grapes (*Vitis*)		
"Adirondack"	II	I
"Bacon"	I+	I
"Brighton"	I	I—
"Catawba"	I	II
"Champion"	I—	II
"Concord"	I	II
"Hartford Prolific"	II	II
"Herbert"	I+	II
"Koshu"	I+	I
"Ives"	I+	II+
"Lady Washington"	I	II+
"Sweet Water"	I++	I
Sand Pears (*Pirus serotina*)		
"Nijisseiki"	I	I
"Kozo"	II	II
"Chojuro"	II	II
Apples (*Malus sylvestris*)		
"Iwai"	III	III
"Jonathan" ("Kogyoku")	III	I+

Name of plant	Chromogen P	Chromogen F
" Rawles Janet " (" Kokko ")	III	I
" Smith Cider " (" Ryugyoku ")	III	II
" King of Tompkins Country (" Hinokoromo ")	III	II

If was noted that the reduction colour of the extract of the leaf of the pear and that of the apple was somewhat different; the former was orange red, the latter more scarlet red, suggesting that different flavones might be present in them.

In the leaf of *Morus alba*, which is very important in sericulture, the chromogenic substance F was found but not the other, while in the leaf of *Iris Kœmpferi*, the reverse was the case, and in the latter, the chromogen content in the leaf was not correlated with the colour of the perigone, some of which are deeply coloured.

TABLE II.

The chromogen content of the leaf of *Morus alba* and *Iris Kœmpferi*.

Name of plant	Chromogen P	Chromogen F	Remarks
Morus alba			
" Mishima "	—	II	
" Akagi "	—	II	
" Ro-so "	—	III	
" Ro-so " Seedling	—	IV	
" Furisode "	—	IV	
Iris Kœmpferi			
No. 1	I	—	The colour of perigone solid hyacinth purple.[1]
No. 2	II	--	Flecked violet purple
No. 3	III	—	Solid Rood's violet
No. 4	III	—	Flecked violet purple
No. 5	I	(Y)	Self pansy violet
No. 6	I	(Y)	White

1.   Nomenclature according to RIDGWAY, R. Color Standards and Color Nomenclature. 1912.

The skin of the young, green grapes was found to be very rich in the chromogenic substance P but it contains only a trace of the chromogenic substance F. It is of interest to find that the "white" varieties, so far examined, contained the chromogenic substance as much as that shown by the coloured varieties. Even in the deep black variety, the reduction colour of the extract of the green skin was only faint, so it seems highly probable that the anthocyanin pigment in the skin of the grape may be formed chiefly from the chromogenic substance P rather than the chromogenic substance F. According to WILLSTÄTTER and ZOLLINGER (1915)[1] the anthocyanin of grape skin (North Italian or hothouse) were œnidin and œnin which are the methyl ethers of delphinidin and delphinin respectively. The chemical investigation of the chromogenic substances in the grape skin is inviting, for it may clear the relation of anthocyanin to the chromogenic substances P and F.

DEZANI found two kinds of the chromogenic substances in the white grapes of which one only is precipitated by lead acetate. By the action of hydrochloric acid, colouring matters are obtained which are analogous to the œnocyanins. The conversion of these substances into colouring matter is due not to oxidation, but probably to hydrolytic scission with simultanious formation of a reducing substance. In the residue from the chromogenic substances there are other substances which give a red colour with alkali. The result obtained by HEDRICK and ANTHONY[2] shows that (1) "white" is a pure, colour, namely "white" x "white" gives only "white": and (2) "white" is recessive to both black and red.

TABLE 12.

Chromogen content of the skin of green grapes

Name of variety	Colour of skin when fully ripe	Chromogen P.	Chromogen F.
" Ives Seedling "	Black	I	VI
" Bacon "	,,	I	VI

1. WILLSTÄTTER, R. and ZOLLINGER, E. H., Ueber die Farbstoffe der Weintraube u. der Heiderbeere. Liebig. 408 : 83, 1915, and 412 : 195, 1916. See also DEZANI, S., loc. cit.

2. HEDRICK, U. P. and ANTHONY, R. D., Inheritance of Certain Characters of Grapes. N. Y. Agric. Exp. Station. Technical Bull. 45, 1915, pp. 19.

Name of variety	Colour of skin when fully ripe	Chromogen P.	Chromogen F.
" Concord "	Black	I +	VI
" Black Hamburg "	,,	I +	VI
" Hervert "	,	I +	VI
" Bryan "	,,	I –	VI
" Delaware "	,	I –	VI
" Othelo "	Red	I +	VI
" Bryant "	,,	I	VI
" Lady Washington "	White	I –	VI
" Vergennes "	,,	II +	V
" Moore's Diamond "	,,	I +	VI
" Niagara "	,,	I +	VI
" Golden Champion "	Amber	I	VI

" Bell," " Esther," " Eaton " (whites), " Highland," " Hartford Prolific " (blacks), and " Iowa " (red) showed likewise the marked colour reaction of the chromogenic substance P.

Apples, pears, oranges, Kaki fruits, strawberries, bananas and other fruits and vegetables were examined, the results of which were listed and given in Table 13.

In certain plants, the chromogen reaction failed when tested just before the formation of anthocyanin. The leaf scale of the bulb of *Lilium tigrinum* is devoid of anthocyanin when it lies underground. But it becomes purple in exposure to sunlight. Even a few hours exposure causes the purple spots to appear on the surface of the yellowish white leaf scale, and the coloured area extends gradually to the entire scales, within a few days. The alcoholic extract of the suitable material, however, shows practically no reaction of either chromogen.

The potato tuber is another example of this kind. Two kinds of white tubers are known. One is such that the tubers are devoid of anthocyanin as long as they are in the ground but by exposure to sunlight, they become deep purple. The other is such that, even when exposed to the light for a long time, no anthocyanin is produced. The extract of both kinds of white tubers showed a very feeble reaction of the chromogens. It seems that the anthocyanin may be formed so rapidly from the raw material in these instances

that there may be no appreciable amount of the chromogenic substance accumulated to show a definite colour reaction.

The body of evidence so far reported seems to point to the following conclusions.

In a number of plants, anthocyanin and the brown pigment (phlobaphene) can be traced to their respective chromogenic substance previous to the formation of the pigments. Both pigments can be formed from the same chromogenic substance by the action of a number of complementary pigment-yielding agencies. The chromogenic substances can be identified as belonging to two groups of substance with respect to certain colour reactions, one of which is designated as chromogenic substance F, (certain flavones and flavonols), and the other as chromogenic substance P of which the chemical nature is unknown.

The formation of brown pigment includes at least the following cases.

1. It is chiefly due to the oxidation and subsequent changes of the chromogenic substance F. Example: the awn of *Oryza sativa* as we shall see later.

2. It is chiefly due to the oxidation and subsequent changes of the chromogenic substance P. Example: the seed coat of the legumes (*Phaseolus vulgaris, Pisum sativum, Glycine soja* etc).

3. It is chiefly due to the oxidation and subsequent changes of the chromogenic substance F and P. Example: the barks of many trees (*Cryptomeria japonica, Pinus parcifolia, Platanus occidentalis* etc).

Besides those chromogens, tannoids, and carotinoids may play a role in the production of the reddish and yellowish brown pigments.

TABLE 13.

Showing the chromogen content of the plant extracts.

Designations: Peri. = peripheral tissue.

Int. = Internal tissue.

(+) sign without the number of the class in the colour scale, denotes the presence of the colour but below the lowest class in the scale. (+) sign with the numeral denotes the colour somewhat deeper than the scale indicated by the numeral. (−) sign designates likewise the colour below the scale.

(×) sign designates the presence of a distinct colour which differs from that of the colour scale.

R = red,   O = orange,   OR = orange red,   B = blue,

V = violet,   M = magenta,   Y = yellow,   G = green,

YG = yellowish green,   Br = brown,   BR = brownish red.

Name of plant	Part examined	Chromogen I'	I'	Remarks.
Gymnosperms.				
Cryptomeria japonica	Lf	III −	V	
,, ,,	Wood & pith.	IV	−	Young twig.
Pinus densiflora	Lf.	IV	V	
,, ,,	Bark	I	VI	Young twig
,, ,,	Wood & pith.	VI −	−	
Larix leptolepis	Lf.	III	III	Young twig.
,, ,,	Wood & pith.	V	−	
,, ,,	Bark	I	V +	
Picea ajanensis	Lf	III	IV	
,, ,,	Bark	I	V	Young twig
,, ,,	Wood & pith.	V	−	
Thujopsis dolabrata	Lf.	III −	+	
,, ,,	Wood & pith.	V	+	
Angiosperms				
Alismataceæ				
Sagittaria sagittifolia var. *longiloba f. sinensis*	Bulb. Peri.	VI	VI	The outer skin is blue.
,, ,,	,, Int.	+	−	White tissue.
Araceæ				
Colocasia antiquorum	Rhizome Peri.	VI	−	The outer skin brown.
,, ,,	,, Int.	VI	−	White tissue
Liliaceæ				
Allium Cepa	Leaf scale	VI	V	
A. fistulosum	Lf.	−	−	Etiolated.
A. Ledebourianum	Lf. scale	+	−	
Erythronium denscanis.	Shoot	−	−	Etiolated part.
,, ,,	Lf	+	II	Green.
Lilium tigrinum	Lf. scale Peri.	+	−	
,, ,,	,, ,, Int.	+	−	
Amaryllidaceæ				
Narcissus sp.	Lf. scale	−	−	

Name of plant	Part examined	Chromogen		Remarks
		P	F	
Narcissus sp	Lf.	—	VI —	
,,	Perigone	—	II —	Yellow colour
,,	Corolla	—	II +	Pale yellow
Dioscoreaceæ				
Dioscorea Batata	Rhizome Peri	VI	±	The skin brown
,,　　　,,	,,　　Int.	V	—	White tissue
Iridaceæ				
Belamcanda punctata	Fruit	VI	—	Green fruit, black when ripe
Bromeliaceæ				
Ananas sativus	Fruit Peri.	II —	II	
,,　　　,,	,,　　Int.	×(Y)	II	
Commelinaceæ				
Commelina communis	Seed	VI	—	Unripe seed, brown when ripe.
Gramineæ				
Agrostis vulgaris	Lf. & culm.	—	VI + [1]	
Avena sativa				
" Tresspass "	,,　　,,	—	IV	
" Kohnoen "	,,　　,,	—	IV	
" Race Horse "	,,　　,,	—	IV	
" Hadaka "	,　　,,	—	IV	
Dactylis glomerata	,,　　,,	+	IV	
Hordeum vulgare				
Spring barley　A	,,　　,,	—	IV	
,,　　,,　B	,,　　,,	—	IV	
,,　　,,　C	,,　　,,	—	IV	
Winter barley　A	,,　　,,	—	V	
,,　　,,　B	,,　　,,	+	IV	
,,　　,,　C			IV	
" Golden Melon "	,,　　,,	—	IV	
Triticum				
" Gypsy "	,,　　,,	—	IV +	
" Red Wave "	,,　　,,	—	IV +	
" Silver Sheef Longlessy "	,,　　,,	—	IV ∓	

1.　The reduction colour of the extract of most of the grasses examined is tinged with orange red hence the colour can be matched better with the scales which are made by the reduced solution of apigenin or luteolin.

Name of plant	Part examined	Chromogen		Remarkes
		P	F	
"St. Louis Grand Prize"	Lf. & culm.	—	IV+	
"Fulcaster"	,, ,,	~	III	
"Castle's Prolific"	,, ,,	—	IV+	
"Imperial Amber"	,, ,,	—	IV+	
"Eclips"	,, ,,	—	IV+	
"Penn Blue Stem"	,, ,,	—	IV+	
"Valley"	,, ,,	—	IV	
"Harvest King"	,, ,,	—	III	
"Pool"	,, ,,	—	III	
"Ruports Grant"	,, ,,	—	IV	
"Mortgage Litter"	,, ,,	—	III	
"Rural New Yorker"	,, ,,	—	IV+	
"Fultz"	,, ,,	—	III	
"Jones Mammoth Amber"	,, ,,	—	IV+	
"Giant Square Head"	,, ,,	—	IV+	
"Klondyke"	,, ,,	—	IV+	
"Dawson's Golden Chaff"	,, ,,	—	IV	
"Kanred"	,, ,,	—	IV+	
"Turkey"	,, ,,	--	IV+	
"Kahrkof"	,, ,,	—	IV	
"Rikuu No. 1"	,, ,,	—	IV—	
Triticum spertum	,, ,,	×(Br)	III	
Zea Mays				
"Koshu"	Seed	×(B)	—	Unripe seed.
Unnamed	,,		—	White dent.
Seeds cereds	Lf. & culm.	(Br)	III	
Setaria italica				
"Honaga"	,, ,,	+	I	
"Tsugaru-wase"	,, ,,	+	I	
"Akaho"	,, ,,	+	I	
"Karasuhashi"	,, ,,	+	I	
,,	Panicle	×(BG)	IV	
"Honaga-sasa-awa"	Lf. & culm.	+	I	
"Eda-awa"	,, ,,	+	I	
,,	Panicle	×(B)	IV	Young head
"Aka-gara"	Lf. & culm.	+	I	
"Bakkiri"	Panicle	×(B)	IV	Young head
Panicum frumentaceum				

Name of plant	Part examined	Chromogen		Remarks
		I'	F	
" Chona "	Lf. & culm	+	III	
" Nigiri "	,, ,,	+	III	
" Bangoro "	,, ,,	+	II	
" Shindai-mochi "	,, ,,	–	III	
" Shiro-hie "	,, ,,	+	III	
" Senkoku "	,, ,,	+	II	
" Onaga-hie "	Head	–	IV	
" Shirobana "	,, ,,	–	–	
" Kisen "	,, ,,	–	–	
" Shiro-sangoku "	,, ,,	–	VI	
" Kobie "	,, ,,	–	–	Young head
" Oso-hie "	,, ,,	III	III	Anthocyanin present.
" Chosen "	,, ,,	VI	VI	Anthocyanin present.
Oryza sativa	(See Table II.)			
" Aikoku "	Lf	–	V	
" Bungo "	,,	–	V	
" Oba "	,,	–	VI	
" Asaterashi "	,,	–	VI	The awn red
" Kurafusagi "	,,	–	VI	The awn brown
" Daikkoto "	,,	–	VI	,, ,,
" Uhei "	,,	–	VI	,, ,, ,,
" Akage "	,,	–	V	,, ,, ,,
" Ono-wase "	,,	–	VI	
" Yamato-chikara "	,,	–	VI	The awn faint yellow.
" Sekiyama "	,,	–	VI	The awn brown.
" Kameno-o "	,,	–	V	Awnless
" Genroku-mochi "	,,	–	V	The awn purple.
" Kawabe-mochi "	,,	–	V	
" Daikoku "	,,	–	VI	Dwarf plant
" Shiki-shima "	,,	–	IV	
Musaceæ				
Musa sp. (Banana)	Fruit Peri.	VI	VI	Skin, fully riped.
,,	,, Int.	IV	–	Flesh, yellowish

1. The colour scale was prepared by the flavone isolated from the leaf of *Oryza sativa* instead of quercetin.

Name of plant	Part examined	Chromogen		Remarks
		P	F	
Zingiberaceae				
Zingiber officinalis	Rhizome Peri.	IV	VI	The skin brown.
" "	" Int.	V	VI	Yellow tissue.
Cupuliferae				
Castanea sativa	Cotyledon	+	—	
" "	Sees coat	IV	VI	Brown, astringent.
Juglandaceae				
Juglans Sieboldiana	Endosperm	—	—	Oily white tissue.
" "	Endocarp	VI	—	
Moraceae				
Morus alba	(See Table II)			
Cannabinaceae				
Cannabis sativa	Lf.	×(OR)	II	
Polygonaceae				
Fagopyrum vulgare	Achene	I	IV	Unripe, colourless.
" "	Lf.	I+	II	
Reynoutria japonica	.	III	I	
Rheum Rhaponticum	"	VI	IV	
Chenopodiaceae				
Spinacia oleracea	Lf.	—	IV	
Nymphaeaceae				
Nelumbo nucifera	Rhizome Peri.	III	V	
" "	" Int.	III	VI	
Cruciferae				
Brassica campestris var. rapifera	Root. Int.	IV	—	The cortex purple.
B. oleracea var. viridis	Lf.	+	III	Yellow lf.
B. oleracea var. capitata	Head	IV	+	White lf.
" " " "	Lf.	V	II	Green lf.
B. oleracea var. botrytis	Head	VI	+	White lf.
" " " "	Lf.	VI	+	White stem.
Rhaphanus sativus				
" Horyo "	Root	×(Br)	IV	White tissue.
"	Lf.	×(BrY)	III	
Malvaceae				
Hibiscus syriacus	Seed	I	V	Unripe seed, brown when ripe.
Balsaminaceae				

Name of plant	Part examined	Chronogen		Remarkes
		P	F	
Impatiens Balsamica	Seed	I	IV	Unripe seed brown when ripe, flower magenta
„ „	,	I	—	Unripe seed flower white.
Rutaceæ				
Citrus Aurantium Jums	Rind. Peri.	×(O)	VI[1]	Ripe fruit.
„ „ „	„ Int.	×(M)	V	White tissue.
„ „ „	Fruit 'pulp'	×(O)	—	
„ „ „	Seed	×(O)	—	
C. Aurantium amara	Rind Peri	×(Br)	III	Ripe fruit.
„ „	Fruit 'pulp'	×(O)	—	
„ „	Seed	×(O)	—	
C. Limonum	Rind Peri	×(Y)	III	
„	„ Int.	×(O)	II	
„	Fruit 'pulp'	×(O)	+	Ripe fruit.
C. Grandis	Rind. Peri.	×(OR)	IV	
„	„ Int.	×(OR)	III	
„	Fruit 'pulp'	×(OR)	+	Pink coloured.
„	Section (carpel)	×	IV	
C. sinensis (Navel)	Rind Peri.	×	III	Ripe fruit.
„	„ Int.	×	I	White tissue.
„	Fruit 'pulp'	×	I	
C. nobilis var. *Unshiu*	Rind. Peri.	±	III	Ripe fruit.
„ „ „	„ Int.	—	III	White tissue.
„ „ „	Fruit, 'pulp'	+	VI	
Vitaceæ				
Vitis	See Tables 10, 12)			
Rhamnaceæ				
Zizyphus vulgaris var. *inermis.*	Fruit	I	VI	Unripe, green fruit.
Saxifragaceæ				
Ribes grossularia	Fruit 'skin'	III	+	Unripe green fruit.
„ „	'fresh' & seed.	III—	+	
„ „	Lf.	I+	I+	
Ribes sp. (currant)	Fruit	III	+	Green fruit.

1. A beautiful reduction colour is partially due to hesperidin which is present in the rind of oranges and by reduction, yields a marked reduction-colour like flavones. This information, the writer owes to the kindness of Prof. K. Shibata.

Name of plant	Part examined	Chromogen I	F	Remarkes
Ribes sp. (currant)	Lf.	I +	I +	
Oenotheraceæ				
Oe. Lamarckiana	Lf.	+	III	
Umbelliferæ				
Oenanthe stolonifera	Root. Peri.	VI	—	
" "	Lf. & stem.	VI —	III	
Daucus Carota	Root. Peri.	+	—	
" "	" Int.	+	—	
Araliaceæ				
Aralia cordata	Lf.	—	I	
Rosaceæ				
Cydonia vulgaris	Fruit. Peri.	II -	VI	Papilla removed which are rich in flavone.
" "	" Int.	I -	+	
Pseudo-cydonia sinensis	Fruit. Peri.	I	VI	
" "	" Int.	I —	+	
Eryobotrya japonica	Fruit 'skin'	I	III	
" "	" 'fresh'	VI	—	
Fragaria chiloensis	Fruit (receptacle) & achenes	II	VI —	Unripe, colourless receptacles
Malus sylvestris				
"Rawles Janet"	Fruit. Peri.	I + +	VI	Unripe fruit
" "	" Int. (cortex of receptacle)	I + +	+	
"Jonathan"	Fruit Peri	I + +	VI	
"	" Int.	I + +	VI —	
"Ben Davis"	" Peri.	I + +	VI —	
" "	" Int.	I	+	
"Smith Cider"	" Peri.	I + +	VI —	
" "	" Int.	I	+	
"Twenty Ounce"	" Peri.	I + + +	VI	
" "	" Int.	I + +	—	
"Iwai"	" Peri.	I	—	
"	" Int.	II	+	
Prunus communis	" Peri.	III	V	
" "	" Int.	III	+	
Pirus serotina	" Peri.	V	—	
Prunus Mume	" "	II	+	Fully ripened fruit
" "	" Int.	II	—	
P. triflora (Sumomo)	" "	II	—	Epicarp deep red.

Name of plant	Part examined	Chromogen		Remarks
		P	F	
Prunus triflora (Hattankyo)	Fruit. Peri.	II +	VI —	
,, ,, ,,	,, Int.	II	+	
Rosa rugosa	Root & rhizome	I	I	
R. multiflora	Lf.	+	I	
,, ,,	Petals	+	II	White petals.
Papilionaceæ				
Indigofera pseudotinctoria	Seed	I	—	Unripe green seed, dark brown when ripe
,, ,,	Pod	I	VI	
Cytisus scoparius	Shoot	× (O)	+	
,, ,,	Bark	III	IV	
, ,,	Wood	+	—	
Phaseolus vulgaris	(See Table 9)			
Ph. radiatus var. *aureus*	(See Table 8)			
Glycine soja	(See Table 20)			
Pisum sativum	Seed	I +	+	Unripe seed, brown when ripe
Vicia Faba	Seed coat	II	× (O)	
,, ,,	Cotyledon	—	—	
,, ,,	Pod	—	V	
Vicia sativa	Lf	—	I	
,, ,,	Seed	II +	× (O)	
Trifolium pratense	Lf	—	II	
T. repens	,,	—	V	
Ebenaceæ				
Diospyros Kaki				
" Tsuruno-tomo "	Fruit. Peri (epi.- & meso-carp)	II	VI	Sweet, with brown spots.
,,	,, Int.	II	+	,,
" Fuyu "	,, Peri.	III	+	,,
,,	,, Int.	III	—	
" Ama-hyakume "	,, Peri.	I	+	Sweet, no brown spots.
,,	,, Int.	I	—	
" Hyakume "	,, Peri.	II	VI	Sweet, brown spotted.
,,	,, Int.	III	—	
" Shogetsu "	,, Peri.	II	VI	,,
,,	,, Int.	III +	—	
" Jiro "	,, Peri	II	VI	,,

Name of plant	Part examined	Chromogen P	F	Remarks
" Jiro "	Fruit. Int.	III	—	
" Hana-gosho "	.. Peri.	II	VI	Sweet, no brown spots.
., ..	.. Int.	III	—	
" Zenji-maru "	.. Peri.	II	V	Sweet, many spots.
,. ..	.. Int.	II+	VI—	
" Haku-nyu "	.. Peri.	III	+	Astringent, no spots.
,. ..	.. Int.	II+	—	,.
" Wase-jisha "	.. Peri.	III	+	..
,. ..	.. Int.	II+	—	,.
Unnamed	.. Peri.	I+	II	
.,	.. Int.	I+	III	..
" Yokono "	., Peri.	III	VI	..
.,	.. Int.	II	+	..
" Sane-nashi "	.. Peri.	II	VI—	..
., .	.. Int.	II+	—	..
" Mishiradsu "	.. Peri.	II+	—	..
..	. Int.	II+	+	..
" Fuji "	.. Peri.	II	VI	,.
..	., Int.	II+	VI—	,.
" Dojo-hachiya "	., Peri.	II	VI	,.
,. ..	., Int.	II	+	..
" Yotsu-ya "	., Peri.	I+	VI—	
..	.. Int.	I+	+	,.
Inayama .,	.. Peri.	II+	V	..
..	.. Int.	II+	VI	,.
Convolvulaceæ				
Ipomœa Batatas	Root. Peri.	—	—	The cortex ' white.'
,. ,.	., Int.	—	—	Yellow tissue.
Solanaceæ				
Solanum Melongena	Fruit	×(BG)	—	Skin deep purple.
S. tuberosum		+	—	
" Nemuro "	Tuber	+	—	Skin green
" .. Seedling "	Peri.	+	—	Stem green
" White Rose "	Lf.	—	IV+	,. ,.
" Hayes Kidney "	.,	—	IV—	,. ,.
Nicotiana Tabacum	Lf.	—	III—	Green leaf.
Datura stramonium	.,	—	—	
.. ..	Flower	×(O)	×(O)	White petal.

Name of plant	Part examined	Chromogen P	Chromogen F	Remarks
Labiatæ				
Mentha arvensis var. *piperascens*	Lf.	—	IV	
Cucurbitaceæ				
Cucurbita moschata var. *Toonas*	Fruit. Peri.	+	—	Fully riped, yellow.
„ „	„ Int.	+	—	
Cucumis sativus	„ Peri.	—	VI	
„ „	„ Int.	—	—	
Compositæ				
Arctium Lappa	Root. Peri.	—	—	
„ „	„ Int.	—	—	
Carthamus tinctoria	Lf.	×(BG)	×(OR)	
„ „	Flower bud	×(BG)	×(OR)	

II.   Genetical Study.

1.   THE MODE OF INHERITANCE OF ANTHOCYANIN AND BROWN PIGMENT IN THE AWN AND OTHER PARTS IN *ORYZA SATIVA*.

In the preceding chapters, certain physiological relations in the formation of anthocyanin and the reddish brown pigments to the chromogenic substances are discussed. We shall now consider the genetical factors relating to the formation of these pigments in the awn, paleas, glumes and the grain of *Oryza sativa*.

(a)   Colour Types of the Awn.

Among the number of cultivated varieties of *Oryza sativa* var. *utilissima* and *O. s.* var. *glutinosa*, many are awned. They may be grouped under the following types with respect to the colour of the awn.

   1.   Awn with anthocyanin.

    a.   Purple.

    b.   Red.

   2.   Awn without anthocyanin.

> a. Brown when fully mature.
> b. Faint yellow when fully mature.

The brown and faint yellow awns are green when young and the alcoholic extract of the green material of the brown awn yields a distinct red colour by reduction but that of the faint yellow, only a slightly red tinge. If oxidase is added to the extract, a marked brown colour is produced in the former, while in the latter, practically none. It proves that the colour of the brown awn is due to the pigment produced by the oxidation of the chromogenic substance at the end of the growing period of the plant. The extract of the matured brown awn gives also a distinct reduction colour showing that a part of the chromogenic substance remains without undergoing any serious change. In the matured awn, the brownish yellow substance, sometimes in aggregates, fills the cell, and when treated with ammonia, yields a deep yellow colour. The relative strength of the chromogen content of certain varieties are given below.

TABLE 14.

Chromogen content of the extract of immature green awn of *Oryza sativa*.

Name of variety	Colour when mature.	Chromogen		Oxidation colour [1]
		P	F	
" Sekiyama "	Brown	—	II	Brown
" Uhei "	,,	—	II—	
" Kura-fusagi "	,,	—	IV	,,
" Meirinsen "	,,	—	III	,,
" Daijo-shiro "	Faint yellow	—	VI	
" Chujo "	,,	—	V	
" Koshin-den "	,,	—	V	Pale yellow
" Yamato-chikara "	,,	—	VI+	
" Tanpo "	,,	—	V+	
" Shirahige "	,,	—	VI	,,
" Nagoya-shiro "	,,	—	VI	,,

Unlike the awn, the leaf does not vary very widely in the chromogen content. The result of the tests made over 120 varieties at the middle of August, 1919, is given in Table 15.

1. Pressed sap of the radish root and hydrogen peroxide is added.

TABLE 15.

Chromogen content of the extract of leaf in *Oryza sativa*.
The colour scale was made by the flavone isolated from the leaf of
Oryza instead of quercetin.

Colour scale		Frequency of varieties with respect to the colour of awn and apex of the paleas.				
		Faint yellow	Brown	Red	Purple	Total
	III	1				1
	IV	3	1		1	5
	V	40	8	20	15	83
	VI	18	12	3	1	34
Below	VI	1				1
		63	21	23	17	124

According to the spectrographic investigation of Y. SHIBATA and KIMOT-SUKI (1918)[1], the absorption spectra of the flavone isolated from the leaf of *Oryza sativa* conformed to these of pure luteolin.

(b) The Cross: Brown × Faint Yellow.

The breeding experiments made by the different investigators in Japan, have already shown that the hybrid between certain varieties having the brown awn and the faint yellow, gave in F_1, the red awned plant. The red colour is due to anthocyanin. The segregation in F_2 takes place by the ratio 9 reds, 3 browns and 4 faint yellows, otherwise the ratio is more complicated.[2] The phenomena are in accord with the well known cases of the flower in *Lathyrus* in which the colourless types produce the coloured one in F_1. The writer obtained the similar results by the following crosses,

"Daikkoto"   × "Togo"

"Kura-fusagi" × "Nagoya-shiro"

The characters studied in the above crosses are the following:

1. SHIBATA, Y. and KIMOTSUKI, K., Spectro-analysis of the Plant Pigments of Flavone Group. I. Jour. Chem. Soc., Tokyo. 39, 771, 1918. (In Japanese)

2. Some of the results obtained by Dr. KATO are briefly summerized in IKENO, S., Zikken-Idengaku. p. 81, 1918. Also in Botanical Abst. 2: 114, Entry 679, 1919.

	Stigma	Awn	Chromogen in awn [1]	Paleas	Glume
♀ "Daikkoto"	Colourless	Brown	I	Buff	Buff
♂ "Togo"	„	Faint yel.	VI	„	„
F_1 "Dai" × "Togo"	„	Red	I+	Brown	Red
♀ "Kura-fusagi"	„	Brown	I	„	„
♂ "Nagoya-shiro"	„	Faint yel.	V	Buff	Buff
F_1 "Kura." × "Nago."	„	Red	I	„	Red

The red awn changes to brown when fully mature and becomes indistinguishable from the brown one at the time of harvest. The purple is much more stable than the red, hence the purple remains unchanged even at the time of harvest. The segregation observed in the F_2 generation was as follows :

TABLE 16.

Showing the result obtained in F_2.

Kind of cross	Awn red	Awn brown	Awn faint yel.	Totals
"Daik" × "Togo" Pt. I	77	14	24	115
„ II	113	27	42	182
	190	41	66	297
Expect. (9 : 3 : 4)	166.96	55.69	74.25	
Probable errors	± 5.765	± 4.537	± 5.933	
Diff. (ob.−expect.)	+23.04	−14.69	−8.25	
"Kura." × "Nago." Pt. I	85	25	32	142
„ II	125	43	68	236
	210	68	100	378
Expect. (9 : 3 : 4)	212.61	70.85	94.50	
Probable errors	±6.536	±5.148	±5.679	
Diff. (ob.−expect.)	−2.61	−2.88	+5.50	

1. One gram dried awn was extracted with 30 cc of a 45 per cent alcohol. Five cc of the extract were reduced by means of one cc of concentrated hydrochloric acid and the due amount of magnesium powder.

In the case of the cross "Daikkoto" × "Togo" reds and browns were often difficult to distinguish accurately owing to the faintness of the red pigment and the rapidity in change to the brownish colour. A considerable deviation from the expectation thus arose, though the observed numbers are fairly close to the approximation to a $9:3:4$ ratio.

Thirty six browns and twelve faint yellows were raised in the next year. If a $9:3:4$ ratio is accepted, we should expect among browns which include reds and browns, two groups of families in the F_3 generation. One of them should throw again red and brown, and the other should not throw red. The ratio of two such families should be $3:1$. We obtained:

	No. of families which threw reds	No. of families which threw no reds	Total
Observed	32	4	36
Expected	27	9	36
Difference	$+5.0\pm1.751$	-5.0	

Among the red throwing families, the following families are expected:

Type of families	Segregation
1.	Red constant occurring once in every nine.
2.	Reds, browns and faint yellows in $9:3:1$ ratio occurring four times in every nine.
3.	Reds and faint yellows in $3:1$ ratio occurring two in every nine.
4.	Reds and browns in $3:1$ ratio occurring twice in every nine.

Among the families which throw no reds, the following families are expected:

Type of families	Segregation
5.	Brown constant, occurring once in every three.
6.	Browns and faint yellowish $3:1$ ratio, occurring twice in every three.

We found:

Type of families	No. of families observed	expected	Difference (ob.—exp.)
1.	3	3	0
2.	7	6	+1
3.	10	6	+4
4.	12	12	0
5.	2	3	−1
6.	2	6	−4
	36	36	

The faint yellows are expected to be constant. Twelve families raised were all constant. The actual numbers are given in Table 31.

In the case of the cross "Kurafusagi" × "Nagoya-shiro", the red colour of the awn was more distinct than the former case, hence the agreement of the expected to the observed numbers was close. In the F_3', was obtained:

Type of families	No. of families observed	expected	Difference (ob.—exp.)
1.	8	7.583	+0.417
2.	31	30.332	+0.668
3.	13	15.166	−2.166
4.	18	15.166	+2.834
5.	6	7.583	−1.583
6.	15	15.166	−0.166
	91	90.996	

Thirty two faint yellow gave all constant families. See Table 32.

(c)   The Cross : Red × Purple.

The relation of the colour of the stigma, awn, palea, glumes and the leaf-sheath was studied by the cross "Hanbun-nento" × "Genrokumochi". The characters involved in this cross which were subjected to investigation were as follows :

	"Hanbun."	"Genroku."	F_1 "Hanbun." × "Genroku."
Awn	Red	Purple	Purple

	"Hanban."	"Genroku."	F_1 "Hanban" × "Genroku."
Stigma	Colourless	Red to purple	Red to purple
Palea	Brown	Purple localized in streaks from the tip to downward on yellow ground colour	Self purple on brown ground colour
Glume	Red	Purple	Purple
Leaf-sheath	Green	Green with purple stripes	Green with purple stripes

Thus we see that the dominant colours are; in the awn purple over red, in the stigma red over colourless, and in the leaf-sheath purple striped over non-striped. A new type of palea was found in the F_1 plant, namely the self purple on the brown ground colour (see Plate I). The brown ground-colour is dominant over yellow, and the self purple is dominant over the above two, being epistatic to brown. A complete linkage is found between the self purple and brown ground colour. The localized purple is always non brown with respect to the ground colour in the paleas. In the F_2 generation, we obtained the following results.

TABLE 17.

Showing the result obtained in F_2.

	Stigma coloured		Stigma colourless		Total
	Pt. I.	Pt. II.	Pt. I.	Pt. II.	
Awn purple	59	49	—	—	108
Awn red	—	—	12	22	34
Total	59	49	12	22	142
Paleas, self purple (deep)	1	6	—	—	10
" " (medium)	18	16	—	—	34
" " (pale)	14	16	—	—	39
" purple localized (prominent)	1	3	—	—	7
" purple (medium)	16	8	—	—	24
" brown	—	—	8	15	23

	Stigma coloured		Stigma colourless		Total
Paleas, yellow	1 ?	—	4	7	12
Total	57 [1]	49	12	22	140
Glume, purple	59	49	—	—	108
„ red	—	—	8	22	30
„ undetermined	—	—	4	—	4
Total	59	49	12	22	142

By summing up the above figures, we obtain

	Stigma coloured & leaf-sheath striped	Stigma colourless & leaf-sheath non striped
Observed	108.	34
Expected (3 : 1)	106.5	35.5
Diff. (ob.—exp.)	+1.5	—1.5

With respect to the colour of the palea :

	Self purple on brown	Localized purple on yellow	Brown	Yellow
Observed	71	31	23	12
Expect. (9 : 3 : 3 : 1)	78.75	26.25	26.25	8.75
Diff. (ob.—exp.)	—4.75	+4.75	3.25	+3.25
Probable errors	±3.959	±3.115	±3.115	±1.932

The above ratios were confirmed by the result obtained in F_3. The actual numbers are given in Table 33.

The coloured stigma, purple awn and glume, self purple palea, and striped leaf-sheath are inherited together. According to HECTOR (1916),[2] the Indian varieties studied at Ducca, may be classified as follows :

(1)   Leaf-sheaths, apiculus of glumes, and stigma coloured.

(2)   Leaf-sheaths and apiculus of glumes coloured, but stigma colourless.

1.   Two plants died.

2.   HECTOR, G. P., Observations on the Inheritance of Anthocyan Pigment in Paddy Varieties.   Memoirs Depart. Agri. India. Bot. Series. 8 : No. 2, 89, 1916.

(3) Apiculus of glumes coloured, but leaf-sheaths colourless.

(4) Apiculus of glumes only coloured. He doubts of classes 3 and 4 really exist. Class 1 is the commonest group. Contrary to Indian varieties, the colourless stigma with green leaf-sheath is the most common type found in Japanese varieties. He observed further, that the colour in the leaf-sheaths and apiculus is due to a colour factor R acting on a chromogen C, and that the purple colour of the stigma is due to a further factor P not present in the leaf-sheath and apiculus, and that the simultaneous presence of all three factors RCP is necessary for the production of any sort in the stigma. PARNELL, RANGASWAMI, AGYANGAR, and RANIAH (1917) have shown that in certain Indian varieties, the purple lining of the internode is coupled with the purple glumes, the purple stigma with the purple axil (purple-colouring of the epidermis on the inside of the sheath) but the purple lining of the internode and the purple glume do not co-exist with the purple stigma and the purple axil.

Among the Japanese varieties studied by the writer, most of those which have a coloured stigma have a purple awn and leaf-sheaths striped, and only in certain varieties, they are separated. The distribution of anthocyanin in Japanese varieties is shown in the following table.

TABLE 18.

Distribution of anthocyanin in the varieties of Japanese rice.

Name of typical variety	Stigma	Awn	Palea (tip)	Palea	Glume	Lf. sheath	Lf. blade
" Murasaki "	Coloured	Purple	Purple	Purple	Purple	Purple	Purple
" Tokachi-wase "	,,	,,	,,	Red	Red	Purple striped	Red striped
" Haguro "	,,	,,	,,	Purple	Purple	Red strip.	—
" Edowase "	,,	,,	,,	—	—	,,	—
" Bozu-karasu "	,,	Awnless	,,	—	,,	—	—
" Uyejini-shirazu "	,,	Purple	Reddish brown	—	,,	—	—
" Genroku-mochi "	,,	,,	—	Purple	Purple	Purple striped	—

1. PARNELL, F. R., RANGASWAMI, AGYANGAR, G. N, and RANIAH, K., The Inheritance of Characters in Rice I. Memoirs Depart. Agri. India. Bot. Series. 9:75, 1917.

Name of typical Variety	Stigma	Awn	Palea (tip)	Palea	Glume	Lf. sheath	Lf. blade
" Choja-bozu "	Coloured	Awnless	—	—	—	Purple striped	—
" Kanta-bozu "	,,	,,	—	—	—	—	—
" Isejiro "	,,	Purple	Purple	—	Purple	—	—
" Gorobei "	Colourless	Awnless	Red	—	Red*	—	—
" Hozoroi "	,,	,,	,,	—	,,	—	—
" Honmra "	,,	Red	,,	—	,,	—	—
" Asaterashi "	,,	,,	,,	—	,,	—	—

The purple and red awn is green when the panicle is in the leaf-sheath. The red colour begins to develop at first at the tip and the base of the awn, a day or two after the panicle has appeared from the leaf-sheath (see Plate I). The colour gradually extends to the entire portion and at the same time increases in intensity. The purple awn is red in the beginning, but rapidly intensifies in colour and becomes deep purple. In the red awn, on the other hand, the red pigment remains unchanged and sooner or later, it is decomposed. A similar change is observed in the glume.

The development of the pigment in the awn is dependent on the illumination. When the panicle is enclosed in the paper bag to ensure self pollination, the pigment develops only slightly. In the stigma, purple anthocyanin is already present even when the panicle is still in the leaf sheath. Thus the development of anthocyanin is seen to have different physiological requirements even in the different parts of the same floral organs.

In the cells of the colourless stigma, flavone can be detected by treating them with ammonia which yield a deep yellow colour. It is quite probable, however, that there may be a colourless stigma having no flavone (chromogen). HECTOR (1916)[1] has shown that the colour of stigma in certain cases, is due to more than three factors.

The anthocyanin pigment in the palea is confined to the epidermis, and the brown pigment to the underlying tissue. The brown pigment is practically insoluble in strong alcohol, but slightly in a weak solution. Fully matured

* The colour indistinct, sometimes obscure.
1. HECTOR, G. P., Loc. cit.

brown paleas were extracted with alcohol for a long time, and the extract was tested for chromogen. Practically no red colour was found by reducing nor by heating with hydrochloric acid.
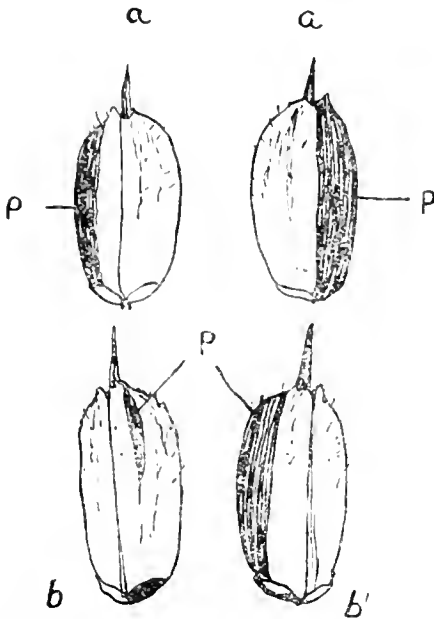
Text fig. 2. Showing the anomalous sectorially pigmented paleas. Born on the panicle of which spikelets were self purple. *a, a'*, same spikelet; *b, b'*, same spikelet seen from the different sides. *p*, purple area.

Among the F, plants certain anomalies which are worthy of mention, were found.

Two spikelets born on a panicle of a plant which bore the red awn and yellow paleas, possessed the brown inferior palea.

Two spikelets born on a panicle of a plant having the spikelets which bore a purple awn, paleas and glumes were sectorially pigmented with purple and yellow (see text fig. 2.)

Two grains were found in a single spikelet in one of the spikelets of a normal plant. The spikelet of *Oryza sativa* normally bears only one grain.

In one plant, both paleas, inferior and superior were found to bear awn. The anomalous awns were short and red coloured. Normally, the inferior palea only possess a long awn.

In one of the spikelets born on a panicle of a plant, the lodicules were found to be modified to small palea-like appendages which were narrow and sharply pointed.

(d)   The Relation Between the Colour of the
Grain and the Paleas.

It is of interest to observe the difference in the kind of chromogenic substance of the brown pigments in the awn and the grain. The colour of the grain of most of the Japanese varieties is pale buff but in few, reddish brown.

The chromogenic substance can be detected in the extract of the milk ripe, green grains of the reddish brown sort but not in that of the pale buff.

TABLE 19.

Chromogen content in the extract of the milk-ripe

grain of *Oryza sativa* [1].

Name of variety	Colour of fully matured grain	Chromogen P	F	Colour of extract with peroxidase	with KOH (boiled)
" Uhei "	Pale buff	—	—	—	Yellow
" Kinoshitamochi "	,,	—	—	—	,,
" Kameno-o "	,,	—	—	—	,,
" Togo "	,,	—	—	—	,,
" Seki-yama "	,,	—	—	—	,,
" Yamato-chikara "	,,	—	—	—	,,
" Akamoro "	Reddish brown	II	—	Orange brown	Deep blue to red[2]
" Haguro "	,,	II	—	,,	,,

As we have already seen the chromogen in the awn belongs to the group of the chromogenic substance F, and in the grain, to the chromogenic substance P.

According to Kondo (1917),[3] the reddish brown pigment of the grain is confined to a single cell layer of the integument of the seed coat. In the dark coloured grain of the foreign sort, the writer observed that the pigment was not confined to the seed coat. An anthocyanin-like pigment was found in the pericarp, namely the layer above the tube cells and even in the grain of the brown sort of Japanese rice, a yellowish pigment was found in the cell of the pericarp.

Parnell et Al[4] have shown that in Indian rice, the red, grey brown, and

1. Three grams of fresh material were extracted with 15 cc of a 40 per cent alcohol.

2. The extract was boiled with caustic potash. A deep blue colour like that produced by the solution of myricetin was found. On cooling, the blue colour changed to red. It may incidentally be mentioned that most of the flavones give a deep yellow colour when treated with caustic potash, but myricetin gives a deep blue instead of yellow.

3. Kondo, M., Untersuchung ueber die Dicke der Reiskleischicht. Bericht. d. Ohara Inst. f. Landwirt. Forsch. 1 : 219, 1917.

4. See also Kikkawa, S., On the Classification of Cultivated Rice. Jour. Coll. Agri. Imper. Univ. Tokyo. 3 : 11, 1912, Parnell et al. Loc. cit.

white grains segregated by the ratio $9:3:4$ in the descendants of certain natural hybrids, and the red grain plants were purple-pigmented whereas the grey-brown plants were unpigmented. A similar case was found in the cross between two Japanese varieties, "Otsubu" × "Haguro". The grain of the former was pale buff ("white") and the latter was reddish brown. In the F_2 plants the following result was obtained.

TABLE 20.

Showing the result obtained in F_2.

"Otsubu" × "Haguro"

Colour of		Colour of grains			Total
Awn	Paleas	reddish brown	yellow brown	pale buff (white)	
Purple	Self purple	119	—	36	155
Purple	Loc. purple	33	—	12	45
Brown	Brown	—	33	11	44
,,	Yellow	—	12	4	16
		152	45	63	260
Expect. $(9:3:4)$		146.25	48.75	65.00	
Diff. (ob.—exp.)		+5.75	−3.75	−2.00	
Probable errors		±5.375	±4.485	±4.007	

The yellowish brown grains were not found in the purple awn plants. The ratios of coloured to white grains in each awn type showed a normal $3:1$ ratio (see Table 20), so it is certain that a linkage relation exists between the genes for the purple awn and for the reddish brown grain. With respect to the colour of the awn, purple and brown showed a $3:1$ ratio, and in the palea, self purple, localized purple, brown and yellow segregated by the ratio $9:3:3:1$ ($155:45:44:16$ observed against $146.25:48.75:48.75:16.25$ expected) as in the case with the cross "Hanbunnento" × "Genroku-mochi", already reported in the section (c). These two crosses differ with respect to the colour of paleas, only from the gene groups which enter from the parental plants, but the manner of segregation in the F_2 generation is the same, thus:

Kind of hybrid	Self purple	Loc. purple	Brown	Yellow
" Hanbun." × " Genroku."	—	♂	♀	—
" Otsubu." × " Haguro."	♂	—	—	♀
F_2 " Hanbun." × " Genroku."	9	3	3	1
F_2 " Otsubu." × " Haguro."	9	3	3	1

The section of the reddish brown grain showed that the pigment was chiefly confined to the single cell layer in the testa as KONDO observed, though in the pericarp, a yellowish pigment also occurred. In the yellowish brown grain, the pigment occurred chiefly in the pericarp and the testa was slightly pigmented. We are dealing, therefore, with the pericarp and the seed-coat colour in two types of the grains, but in the fully ripe grain, the two parts are hardly distinguishable unlike the bean in which they are differentiated into the pod and the seed coat.

2. The Mode of Inheritance of Anthocyanin and Brown Pigment in the Seed Coat of *GLYCINE SOJA*

Nothing perhaps excels the seed coat of the legumes in diversity of the colour characters exhibited by the plant except the flowers of some ornamental plants. As we have already seen, the seed coat of the coloured bean of the legumes is rich in the chromogenic substance previous to pigmentation. Some data on the genetical behavior of the colour characters in the seed coat of soy bean (*Glycine Soja*) are discussed in this chapter.

(a)   Colour Types of the Seed Coat.

The different varieties of Japanese soy beans may be classified under the following types with respect to the colour of the seed coat.

I. Self-colour type.

    1   Black (deep purple).

    2. Reddish brown.

    3. Brown with or without a green tinge including different shades of brown.

    4. Buff.

      5.   Green.

      6.   Yellow.

  II.   Parti-colour type.

      1.   Black mottled, the ground colour brown with or without a green
tinge.

      2.   Black patch around the hilum. The ground colour is either
yellow or green.

      3.   Dark brown patch around the hilum, the ground colour is either
green or yellow.

      4.   Blue tinged around the hilum. The ground colour either green
or yellow. The margin of the blue tinge is not so distinct as
in 2 and 3.

The chromogen can be detected in the immature green seed of all the coloured types, except the green and yellow. The chromogenic substance P is abundant but the chromogenic substance F is very scarce or absent. In the green and yellow, both are nearly absent. Hence the different types can be distinguished into two groups with respect to the chromogen. One includes those which give a marked chromogen reaction when the seed is still green and the other includes those which give only a slight or no reaction. In this regard, the green and yellow correspond with the white type of the common garden bean and Adzuki-bean (see Tables 8, 9).

Since the reaction of the chromogenic substance F is feeble in the seed just before the formation of the pigment, the latter must be formed from the chromogenic substance P which is present. In the leaf, however, the chromogenic substance F occurs in a considerable amount and can readily be isolated as yellow crystals. The following table will give a general idea of the distribution of the chromogens in the seed coat and the leaf of different varieties of soy-beans.

TABLE 21.

Chromogen content in the extract of unripe, green seed,
and leaf of *Glycine soja*.[1]

Name of variety.	Colour of seed when mature.	Chromogen in seed		Chromogen in seed oxidation colour[2]	Chromogen in lf.	
		P	F		P	F
" Kurodaidzu-ko "	Solid black	III	—	RBr.	—	III
" Goishi "	,,	III	—	RBr	—	III +
" Goishi " (flower purple)	,,	III	—	,,	—	III +
" Nedzumi-meta "	Brown	IV	—	OBr	—	III —
" Akakzuka "	,,	II	+	,,	—	IV
" Cha "	,,	II	—	,,	—	III +
" Haiiro "	,,	III	+	,,	—	III
" Beni-iro-daidzu "	Red brown	III	—	,,	—	III —
" Akanedzumine "	,,	III	+	,,	—	III
" Madara "	Black mottled brown	III	—	,,	—	III +
" Juseita "	Black patched	IV	—	,,	—	III
" Kura-kake "	,,	III	—	,,	—	III
" Achmauri "	Solid black	III	VI	,,	—	III
" Tanishi "	Blue tinged yellow	V	—	YBr	—	III +
" Tora-mame "	Solid black	IV	—	OBr	—	III +
" Goku-ao "	Green (green)	—	—	—	—	III
" Aobishi "	,, ,,	VI	—	—	—	IV
" Uma-daidzu "	,, ,,	—	—	—	—	III
" Goyo "	,, ,,	—	—	—	—	III
" Ao "	,, ,,	—	—	—	—	III
" Toyo-naga "	Green (yellow)	—	—	—	—	III —
" Dateao "	,, ,,	—	—	—	—	III
" Yoshioka "	,, ,,	—	—	—	—	IV
" Shakujo "	Yellow (yellow)	—	—	—	—	III +
" Shiro sota "	,, ,,	—	—	—	—	III
" Omejiro "	,, ,,	—	—	—	—	III
" Yuki no-shita "	,, ,,	—	—	—	—	III
" Chogetsu "	,, ,,	—	—	—	—	III
" Kimusume "	,, ,,	—	—	—	—	IV

1. The extraction was made with 5 cc of a 10 per cent. alcohol to each gram of fresh beans and with 10 cc for leaf.

2. Pressed juice of potato tuber and hydrogen peroxide added. The designations of colours are the same as those used in Table 13.

3. The colour of cotyledon.

Name of variety	Colour of seed when mature		Chromogen in seed			Chromogen in lf.	
			P	F	oxidation colour	P	F
" Sennari "	..	..	—	—	—	—	III
" Kariba takiya "	.	..	VI	—	—	—	III —
" Shiro nedzumi "	..	..	—	—	—	—	III
" Fukui-shiro "	..	..	—	—	—	—	IV
" Shonai-wase "	..	..	—	—	—	—	III
" Shiro hachikoku "	..	.	—	—	—	—	IV
" Abura mame "	..	..	—	—	—	—	III

The purple and blue pigments are anthocyanins. Both anthocyanin and brown pigments are confined to the epidermis existing in the same cell. When a common black bean is boiled with an alkaline solution, the colour of the solution becomes blue to green at first, but soon changes to deep wine red owing to the extraction of the brown pigment in alkali.

The peroxidase was tested in a number of varieties at the stages previous to pigmentation of the seed coat. The reaction was very distinct in the seed coat of all the coloured types as well as in the yellow and green ones, but the direct oxidase reaction failed by alpha naphtol, benzidine, myricetin and guaiacum. It was often noted when alpha naphtol was applied, the reaction was very faint in the epidermis even in the presence of hydrogen peroxide. There could be found no definite difference with respect to the peroxidase reaction exhibited by the seed coats of beans which contain the chromogenic substance and those lacking it;

In the black patched bean, however, the part where the anthocyanin colour will appear in a patch, yielded a deep purple or brown colour by immersing the whole bean which was previously treated with alcoholic solution of benzidine or myricetin, in a dilute solution of hydrogen peroxide. The remaining part where anthocyanin will not be formed at all, yielded less distinct colour in the case of benzidine and nearly failed in the case of myricetin. The chromogenic substance was detected in the tissue of the non-black part. The alcoholic extract of the portion gave a slight red colour by heating with hydrochloric acid.

The above observation seems to point out the fact that at the time of pigment formation, the black patched portion of the seed coat contains more

active peroxidase system than the rest of the portion where the development of the anthocyanin pigment is inhibited, in spite that the chromogenic substance can be detected in a slight extent.

The above observation agrees with the findings of KEEBLE and ARMSTRONG (1912)[1] who have shown the parallelism extisting in the distribution of anthocyanin and peroxidase in the corolla of *Primula sinensis* and in others.

When the seed coat is still green just previous to the formation of anthocyanin, a distinct red colour develops at the portion of black patch by treating the bean with hydrochloric acid in cold. It shows that the anthocyanin pigment is already present in a colourless state.

Oxidation seemed to accelerate the development of anthocyanin in the seed coat of the soy bean. Slightly coloured beans rapidly deepened in colour if the pod was opened and exposed to air. Injury also accelerated the development of the pigment. The portion near the injury became purple at first on exposure to air[2]. Conversely the exclusion of air retarded the development of the pigment. The slightly red-coloured beans ceased to develop the purple pigment when kept in a closed chamber in which the air was replaced by hydrogen gas. Similar phenomena were observed in ripening grapes. In both cases, light had no influence.

(b)   The Cross : Blue Tinged Yellow × Brown and
the Reciprocal.

The colour of the seed coat of the parental plants are the following :

"Tanishi." Yellow with a tinge of blue colour which is most prominent around the hilum, fading gradually further beyond.

"Haiiro." Brown with a tinge of greyish green colour.

The F_2 seeds produced on the F_1 plant were green with a pale blue tinge as in "Tanishi" (see Plate 1). In F_2 solid blacks, and non-tinged greens and yellows were found, together with the parental type, by the following numbers.

1.   KEEBLE, F. and ARMSTRONG, E. F., The Role of Oxydases in the Formation of the Anthocyan Pigment of Plants. Jour. Gent. 2 : 277, 1912.

2.   KEEBLE, F. and ARMSTRONG, E. F., Loc. cit.

TABLE 22.

Showing the results obtained in F_2.

"Tanishi" × "Haiiro."

	Blue-tinged		Non-tinged		Black	Brown	Total
	Green	Yellow	Green	Yellow			
Ob.	19	6	6	0	7	3	41
Exp.	17.30	5.77	5.77	1.92	7.69	2.56	41
Diff.	+1.70	+0.23	+0.23	−1.92	+0.69	+0.44	

"Haiiro" × "Tanishi"

	Blue-tinged		Non-tinged		Black	Brown	Total
	Green	Yellow	Green	Yellow			
Ob.	23	13	1	2	3	3	48
Exp.	20.25	6.75	6.75	2.25	9.00	3.00	48
Diff.	+2.75	+6.25	−2.25	−0.25	−6.00	0	

The calculated ratio is $27 : 9 : 9 : 3 : 12 : 4$. A relative small number in the F_2 plants made the determination of the exact ratio somewhat uncertain but by the F_3 plants, the above ratio was confirmed.

TABLE 23.

Showing the segregation of the offspring of the
heterozygous blue-tinged green F_2 plants of the cross.

"Tanishi" × "Haiiro."

F_2 family no.	Blue-tinged		Non-tinged		Black	Brown	Total
	Green	Yellow	Green	Yellow			
4	18	5	4	3	5	3	38
15	16	6	2	1	9	3	37
30	32	8	3	2	11	2	58
31	30	6	19	2	20	7	84
Total	96	25	28	8	45	15	217
Expect.	91.55	30.52	30.52	10.17	40.69	13.56	
Probable errors	±4.906	±3.454	±3.454	±2.011	±3.816	±2.405	
Diff. (ob.-exp.)	+4.45	−5.52	−2.52	−2.17	+4.31	+1.44	

The rest of the F_3 families agreed with the expectation except three which were apparently contaminated by accidental crossing; hence they were discarded. The actual numbers are given in Table 34. See also Table 29.

(c).   The Cross: Buff × Black.

The colour of the seed coat of a variety "Ware-mame" is buff, and that of a variety "Achunuri" is solid black with peculiar mesh-like, white markings which are due to the small breaks of the epidermal tissue exposing the colourless, underlying tissue of the seed coat (see Plate 1). The F_1 seeds born on the F_1 plant of the hybrid between them were self black. In F_2 self blacks, imperfect blacks, and browns were found with the following numbers.

TABLE 24.

Showing the result obtained in the F_2 generation of the
cross "Waremame" × "Achunuri"

	Self black	Imperfect black	Brown	Buff	Total
Obs.	33	9	6		48
Exp.	27	9	9	3	48
Diff.	+6.0	0	−3.0	−3.0	

The expected ratio is $9:3:3:1$. The buff was not found in the F_2 plants owing to the small number of individuals. In F_3 families derived from the heterozygous self blacks, buffs were found in the expected ratio.

TABLE 25.

Showing the result obtained in F_3 families derived from the
heterozygous self black F_2 plants.

F_3 family no.	Self black	Imperfect black	Brown	Buff	Total
3	21	9	2	1	33
4	31	4	13	1	49
6	46	18	19	4	87

F_3 family no.	Self black	Imperfect black	Brown	Buff	Total
	10	4	1	1	16
12	12	1	1	5	22
18	26	8	1	2	16
19	35	13	13	6	67
23	21	7	5	4	11
25	23	9	7	3	42
26	21	15	14	5	56
27	26	10	3	3	12
33	10	11	4	7	7
Total	315	115	98	43	571
Expected	322.18	107.06	117.06	35.69	
Probable errors	±7.181	±6.291	±6.201	±3.962	
Diff. (ob.-exp.)	−6.18	+7.94	−9.06	+7.31	

What is designated as imperfect black is a new type. It differs from the self black by the incomplete development of the anthocyanin pigment, resulting in the brown ground-colour being made visible (see Plate I). The ground colour of the imperfect black appeared to be brown instead of buff, but in the F_4 generation, they threw only imperfect black and buff but no brown. It seems therefore that the buff colour was deepened by the action of the gene which develops the anthocyanin in the same epidermal cell. The present instance resembles that of the palea colour observed in the cross "Hanbun-nento" × "Genroku-mochi" in which the self purple was completely linked with the brown ground-colour and the localized purple excluded the latter. In both cases, the full development of anthocyanin is in some way associated with the brown pigment.

TABLE 26.

Showing the segregation of the offsprings of imperfect black
F_2 plants.

F_2 family no	Black imperfect	Brown	Buff	Totals
17	26	—	—	26
35	27	—	—	27
34	14	—	3	17
36	35	—	9	44
38	26	—	5	31
39	39	—	15	54
40	4	—	2	6
41	5	—	1	6
	176		35	211

An approximation to a dihybrid ratio was confirmed by forty six families raised in the F_3 generation. The details are given in Tables 30 and 35.

The buff is found to be the most recessive character to any other one in the colour characters so far studied. Since the chromogenic substance can be detected in the unripe, green seed of buffs, browns, and blacks, but is nearly absent in yellows and greens, and further that yellows and greens are dominant over the former colours, it must be concluded that an inhibitor for the development of the pigment is present in the green and yellow.

A mention may be made regarding the brown character. We can distinguish several browns which differ more or less in hue and shade but exact discrimination is very difficult. If it is made among the segregates, the lighter shade appears to be dominant over the deeper one. When the distinctly reddish brown such as we see in the seed coat of a variety " Aka-nedzumine " is crossed with the brown like that we have already dealt with (" Haiiro "), the reddish brown behaves as a single recessive to brown. The F_2 seed of the cross " Aka-nedzumine " × " Haiiro " was brown like that of the father which is brown with a greyish green tinge. In F_2, reddish brown and brown, regardless of the green tinge, segregated in the following number :

	Reddish brown	Brown	Total
Observed	69	19	88
Expected	66	22	88
Diff. (obs.-exp.)	+3.0	−3.0	

The hybrid between "Kari-mame" and "Akadzuka" in which the yellow and reddish brown were crossed, produced the yellow in the F_1 plant, and in F_2 the following segregation was observed.

TABLE 27.

Showing the result obtained in the F_2 of the cross
"Kari-mame" × "Akadzuka."

Plant No.	Green	Yellow	Black	Brown	Reddish brown	Total
I	57	29	14	6	4	110
II	21	11	7	—	4	43
	78	40	21	6	8	153
Expect.	86.062	28.687	28.687	7.172	2.391	
Probable error	±4.139	±3.256	±3.256	±1.763	±1.044	
Diff. (obs.-exp.)	−8.062	+11.313	−7.687	−1.172	+5.609	

The expected ratio is $36:12:12:3:1$. Here again the deeper brown is shown to be recessive to lighter brown. A more detailed analysis of the brown characters is under way, and the result will be reported as data become available.

Speaking in general, the inhibited colour of the seed coat can be guessed by the colour of the hilum and that of the narrow ring around it. In the present communication, the colour of the hilum and the ring is not considered.

3.   AN INTERPRETATION OF THE RESULTS.

It is a well known fact that there are at least two groups of genes

present in relation to the formation of anthocyanin pigments in plants. One
of them includes those which are known as the chromogen factors, and the
other includes those which are complementary to the former. A complete
system provided by the union of these genes produces the plant in which
the formation of anthocyanin pigment is realized. To designate those genes
C is often used for the chromogen, and R for the complementary one. The
most simple case is the counterpart of two genes C and R. We may denote
those genes which are related to the formation of the chromogenic substance
in plants by 'chromogens' (C) and those which are related to the formation of
any biochemical agency, by means of which the chromogenic substance is
converted to a coloured anthocyanin or brown pigment, by 'chromopheleins'
(R, O, etc.). According to the view put forward by Miss WHELDALE, the
chromogen factors in the flower of *Antirrhinum* are related to the formation
of certain flavone glucosides (glucoside of apigenin and luteolin) and the
chromopheleins are related to certain oxidizing agencies probably the
peroxidases.

It must clearly be understood that the phenomena of inheritance and
development are of different kinds, and the data of the latter should not be
confused in interpreting the genetical data. The factor is such an entity of
the organism that by its means certain groups of biochemical reactions are set
free to build up the character which is the phenotypic expression of the
gene. The biochemical reactions and their products alone are dealt with as
physiological and developmental data. Some of them can well be regarded
as the clue to the difference in the genetical units, but these phenomena
themselves are nothing to do with those of inheritance. A well marked,
different biochemical phenomena may not necessarily correspond with the
difference in their genetical potency.

It is an impossible task to know all the biochemical changes which are
governed by a given gene; all we can attempt, if at all, is to find certain
correlations between the known biochemical facts and the genetical data, by
which the chief function of the gene may be inferred. Such an attempt may
be useless or may fall short of the aim. But, as the writer believes, genetics
aims to discover not only the laws of the mechanism of distribution of
hereditary units, but also the links between the gene and the actual

biochemical or physiological processes in the somatic cells that are set free by the corresponding genetical make-up.

In the case of the colour characters in the awn of *Oryza sativa*, we are apparently dealing with instances similar to those that were observed by Miss WHELDALE in *Antirrhinum* and BATESON in *Lathyrus*. Suppose a pair of genes *C* and *c* are concerned. The gene *C* produces the chromogenic substance in the brown awn to such an amount that it can readily be detected in the extract and by *c*, the production of the same substance is as much as ten to twenty times less than that produced by *C*. Consequently the faint yellow awn appears to be devoid of chromogen.

The oxidation and subsequent changes of the chromogenic substance leading to the formation of brown pigment may be due entirely to post mortem changes and may have no relation to the action of a gene whatsoever. If any gene is concerned, we may suppose the following possibilities.

The gene *C* has the simultaneous action of converting the chromogenic substance to the brown pigment in which the oxidation plays an important role.

Or we may suppose that another gene *O*, a chromophelein, which converts the chromogenic substance to the brown pigment, and the genes *C* and *O* are so linked each other that they may be considered as a single gene complex. In the awn of *Oryza*, and in the seed coat of *Glycine* as we shall see later, the chromogenic substance and certain brown pigments which are the oxidation product of the former, appear to be due to the action of a single gene. Wherever the chromogenic substance is produced, it is invariably converted to the pigment of phlobaphene nature, unless the inhibitory gene enters into the system. In this connection, it is of interest to refer the findings of WOLFF, WOLFF and ROUCHERMANN[1] and Mrs. WHELDALE ONSLOW (1919),[2] who have shown in a number of cases that the reaction of direct oxidase is invariably associated with the presence of the chromogenic substance.

If the latter assumption is adopted, the genes concerning the formation of brown awn may be designated by $\widehat{CO}$ and the faint yellow awn by $\widehat{co}$.

1. WOLFF, J., Loc. cit.
   WOLFF, J., and ROUCHERMANN, N. Loc. cit.
2. WHELDALE ONSLOW, M., Oxidizing Enzymes. I. The nature of the " peroxidase " naturally associated with certain direct oxidizing systems in plants. Bioch. Jour. 13 : I, 1919.

Further we admit that the gene R is present in the faint yellow awn plant, and by the completion of the system provided by the genes CR ($\widehat{COR}$), the chromogenic substance is converted to red anthocyanin, but by cR ($\widehat{coR}$) and cor ($\widehat{cor}$) the system is incomplete. The parental faint yellow plant may therefore be designated by cR ($\widehat{coR}$) and the brown plant by Cr ($\widehat{COr}$). The red awn F_1 plant is Cc Rr ($\widehat{COcoRr}$) and by selfing, the following zygotic series would arise in F_2 by the ratio $9:3:3:1$, viz., CR ($\widehat{COR}$), Cr ($\widehat{COr}$), cR ($\widehat{coR}$), and cor ($\widehat{cor}$), and in which the last four would be faint yellows giving rise to 9 reds, 3 browns and 4 faint yellows. The assumption covers the numerical ratio observed in the F_2 and F_3 generations.

Let us suppose in another way that the brown awn may have the genetic composition COr and the faint yellow cOR, in which O is the gene common to both of the parental plants. It is necessary to suppose that no red anthocyanin should be formed by cOR in which the chromogenic substance produced is only in such a small amount that no anthocyanin is formed from it even in the presence of OR. If however, the reduction processes set working by the gene complex here concerned are just as powerful as we provide in vitro by means of hydrochloric acid and magnesium powder, even a trace of the chromogenic substance should be converted to the coloured anthocyanin, for, we can readily detect even a trace of the chromogenic substance ($1:20,000$) by a distinct pink colour by reduction.

In the case of the cross " Hanbun-nento " $\times$ " Genroku-mochi ", in which the purple and red awn are concerned, the basal system of anthocyanin formation CR is complete in both of the parental plants. If we let the gene R' convert the red anthocyanin to purple, the purple awn may be designated by CRR' and the red by CRr'. The designation CRR' may be substituted by a single letter, say P, and CRr' by p. Since we observe the stages of the change, chromogen → red pigment → purple pigment in the plant, CRR' seems to represent the actual phenomena occurring in the sporophyte.

In a number of cases reported, the purple colour is dominant over the red.[1] In *Antirrhinum* Miss. WHEDALE (1914)[2] found that orange anthocyanin

1. See summary in BATESON, W., MENDEL's Principles of Heredity. Third edition. 1913. WHELDALE, M., Anthocyan Pigments of Plants. 1916.

2. WHELDALE, M., Our Present Knowledge of the Chemistry of the Mendelian Factors for Flower Colour. Jour. Genet. 4:8, 1914.

was the derivative of apigenin and rose doré and magenta from luteolin. Two factors are necessary to convert the chromogen (luteolin) to magenta but only one is essential to rose doré. Thus

yyiiRRbb	*yyiiRRBB*	White
YYIIrrbb		Ivory (apigenin)
YYiirrbb		Yellow (luteolin)
YyiiRrbb		Orange
YyiiRrBb		Crimson
YyIiRrbb		Rose doré
YyIiRrBB		Magenta

in which *I* is a dominant ivory factor, inhibiting the formation of luteolin. *Y* is the factor for yellow which is due to apigenin, *R* and *B* are the factors which convert the chromogen to anthocyanin.

The case of *Linaria maroccana*, studied by CORRENS (1912) was as follows: Red is dominant over white, and purple over red. At present his interpretation of the above case is hardly to be maintained. He dwelt upon the fact that anthocyanin is red in acid and blue in alkali and tried to interpret the factor difference of purple and red by that of acidity in the cell sap. But such seems to be unlike the usual case. HAAS (1916) found that the cell sap containing blue anthocyanin is acid or neutral but rarely alkaline if acidity is determined by the hydrogen gas chain.

WILLSTÄTTER attempted to explain the variation in the colour of cyanidin from red to blue by the quinonoid structure of the molecule. The phelolic character of the benzene ring allows the formation of salt with alkali, the red is the acid salt (oxonium salt) the blue is the potassium or metallic salt (alkali phenolate) and the violet is the anhydride of the pigment. But his hypothesis hardly explains how the deep blue anthocyanin can exist in the cell sap of the plant which is acid in reaction and further that an addition of alkali destroys the blue anthocyanin rather than deepening the colour.

A new explanation of the causes of variation in the colour of flowers has been put forward by K. SHIBATA, Y. SHIBATA, and I. KASHIWAGI (1919) based

1. CORRENS, C., Die Neue Vererbungsgesetze. 1912.

2. HAAS, A. R., The Acidity of Plant Cells as shown by Natural Indicators. Jour. Biol. Chem. 27 : 233, 1916.

3, SHIBATA, K., SHIBATA, Y., and KASHIWAGI, I. Loc. cit.

upon experimental evidence, that the metal organic or complex compounds of
reduced flavonol glucoside

$$\left[\text{(sugar)}\left(\begin{array}{c}\text{MeX}\\|\\\text{O}\\\\\\\text{OH}\\|\\\text{OH}\end{array}\;-\text{OH}\right)\right]\left[\text{MeX}_2\right]_n$$
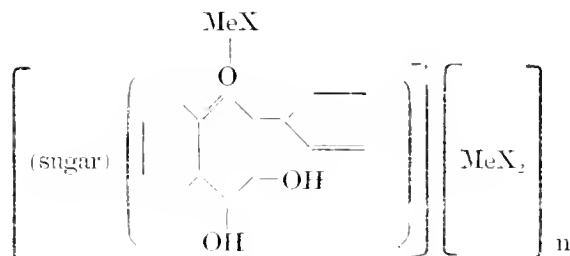
are the most important factor in the production of flower colours. The blue
anthocyanins are complex compounds of reduced flavonol glucosides, which
possess several hydroxyl groups belonging to the flavonol nucleus besides those
of sugar molecules, and the metal with which they are co-ordinated is probably
calcium or magnesium, for salts of these metals are always present in the
plant cells. The violet, violescent red or red pigments are either the analogous
metallic complex compounds of flavonol glucosides, which contain fewer of the
auxochrome hydroxyl groups or are a mixture of the blue pigments and their
decomposition products by excess of acids, i.e., the red oxonium salts of R.
WILLSTÄTTER.

It is likely to be inferred then that the purple and red anthocyanins
formed in the awn and in other parts of *Oryza* are the derivatives of the same
chromogenic flavonol glucoside and the purple is the complex salt of the red
anthocyanin which is formed at first in the cell by the reduction of the
chromogenic substance. The latter part of the changes may be due to the
action of gene R. Indeed, it can be observed that the extract of the slightly
red coloured awn yielded a more intense red colour by reduction than that
produced by a simple addition of hydrochloric acid, and the faintly coloured
extract of red and purple anthocyanins that is due to isomerization, attained
a bluish hue by the addition of $ZnCl_2$ and a reddish hue by $CaCl_2$. The
gene R' may therefore be referred to the agencies which set free the reactions
leading to the formation of a purple complex salt from red anthocyanin with
the existing metallic salts in the cell.

With respect to the colour of the paleas, the following hypothesis may
be provided. Let B be the gene for the brown ground-colour, b for the non

brown. The chromogenic substance of the brown pigment in the paleas was tested at the time previous to pigmentation but failed. Therefore it is evident that the chromogenic substance of the brown pigment in the palea is different from that of the awn which gives rise to the red anthocyanin by the action of the R gene. But B has a specific relation to the formation of purple pigment in the epidermis, inasmuch as the full colour in the purple palea is always associated with the brown ground-colour, and the localized purple excludes the latter. It appears therefore that either B has a simultaneous action on extending the purple pigment to the entire surface of the palea or that the phenomenon is due to another gene which is completely linked with B.

The formation of any purple pigment in the palea appears to be due to another group of genes which are similar in kind to that which affected the awn, inasmuch as the purple awn is completely linked with any purple present in the palea but no red ever occurs in the latter. Let P' be the gene for the presence of purple pigment in the palea, and p' for the absence of the same. Further admit that P' and P are linked. Thus

" Hanbun-nento " $PPp'p'BB$ Awn red, paleas brown.
" Genroku-mochi " $PPP'P'bb$ Awn purple, paleas purple localized.
F_1 " Hanb." × " Genrok." $PPP'p'Bb$ Awn purple, paleas purple.

The F_1 plant is heterozygous to P' and B, since P' and P are linked. In F_2 we expect the following genotypes to occur;

| Genotype | Phenotype | | Designation |
	Awn	Paleas	
$PP'B$	Purple	Self purple with brown	PP
$PP'b$	..	Localized purple without brown.	P
$pp'B$	Red	Brown	B
$pp'b$	,,	Yellow	Y

We should expect therefore the following segregation in F_3 with respect to the colour of paleas.

Genotype of F_2 plant		Segregation in F_3	Ratio.
$PP'BB$	1	PP	Const.

Genotype of F_2 plant		Segregation in r_3	Ratio.
$P'P'Bb$	2	$PP : P$	$3 : 1$
$P'p'BB$	2	$PP : B$	$3 : 1$
$P'p'Bb$	4	$PP : P : B : Y$	$9 : 3 : 3 : 1$
$P'P'bb$	1	P	Const.
$P'p'bb$	2	$P : Y$	$3 : 1$
$p'p'BB$	1	B	Const.
$p'p'Bb$	2	$B : Y$	$3 : 1$
$p'p'bb$	1	Y	Const.

The actual result obtained is given in the following table.

TABLE 28.

Showing the result obtained in F_3 of the cross
" Hanbun-nento " × " Genroku-mochi ".
See also Table 33.

Segregation	Ratio	No. of families observed	Expected	Diff. (ob.—ex)
PP	Const.	1	4.1875	−3.1875
$PP : P : B : Y$	$9 : 3 : 3 : 1$	15	16.7500	−1.7500
$PP : B$	$3 : 1$	9	8.3750	+0.6250
$PP : P$	$3 : 1$	10	8.3750	+1.6250
P	Const.	7	4.1875	+2.8125
$P : Y$	$3 : 1$	13	8.3750	+1.6250
B	Const.	3	4.1875	−1.1875
$B : Y$	$3 : 1$	5	8.3750	−3.3750
Y	Const.	4	4.1875	−0.1875

If we regard the gene $P = CRR'$, $p = CRr'$ as already discussed, P' may also be regarded as a complex of genes CRR' but p' must differ from p, inasmuch as in the paleas, purple and non purple are allelomorphic, but no red ever occurs, whereas in the awn, purple and red are allelomorphic to each other. It can be imagined that in p', crr' behave as a single unit, allelomorphic to the complex CRR'. Else P' and p' may differ only in C but contain R and R' providing that cRR' forms no anthocyanin.

With respect to the colour of the grain, let two pairs of genes O' o' and C c' be responsible. The chromogen C produces the chromogenic substance P in the testa and in pericarp, and c' produces practically none. The gene O' converts the chromogenic substance to a reddish brown pigment especially in the testa and o' to a less extent. Thus by $C'O'$ the reddish brown grain is formed and by $C'o'$ the yellowish brown grain. The parental reddish brown-grain plant may be assumed to be $C'O'$ and the "white"-grain plant $c'o'$. The $9:3:4$ ratio would arise in F_2 by selfing the F_1 plant $C'c'O'o'$. Thus

$C'O'$	9	Reddish brown
$C'o'$	3	Yellowish brown
$c'O'$	3	" White "
$c'o'$	1	,,

With respect to the colour of the paleas, the segregation in F_2 was similar to that of the cross "Hanbun-nento" $\times$ "Genroku-mochi", so we may assume that the analogous genes are concerned in the cross "Otsubu" $\times$ "Haguro" in which the grain colours are studied. But one of the genes for the grain colours probably O' is completely linked with the gene for the purple colour of the palea. Suppose O' is linked with P' but C is independent of the latter, we expect the following segregation in F_2.

$BP'O'C'$	27	Awn purple, palea self purple,	grain reddish brown.
$BP'O'c'$	9	,,	,,	" white "
$bP'O'C'$	9	,,	localized purple	reddish brown.
$bP'O'c'$	3	,,	,,	" white "
$Bp'o'C'$	9	brown	brown	yellow. brown.
$Bp'o'c'$	3	,,	,,	" white "
$bp'o'C'$	3	,,	yellow	yellow. brown.
$bp'o'c'$	1	,,	,,	" white "

If reddish browns, yellowish browns and "whites" are added together irrespective of the colour of the paleas, we obtain $36:12:16$ or $9:3:4$ ratio. The ratio of coloured to non coloured grains in each colour types of the paleas is $3:1$ showing that the gene C' is independent of P' and O'.

As we have already seen, green and yellow seed coat of the soy beans are dominant over black, brown and buff. The green and yellow contain

practically no chromogenic substance whereas the rest of them is prominent. This is to indicate that a dominant inhibitor is present in the green and yellow. Let G be the gene for the green colour and g for the yellow. Further we assume that C and c are the chromogens. The amount of chromogenic substance produced by c is less than that produced by C. Let O be the chromophelein which converts the chromogenic substance to brown pigment and o to reddish brown. It is assumed that the same chromogenic substance is converted to the purple anthocyanin by R but not by r. The gene I inhibits the full development of the pigment in the seed coat and by i no such effect is done. The inhibitory action of the gene I seems to extend to the action of C and R. Accordingly the different colour types may be designated as follows:

$COGRI$	Blue tinged green
$COgRI$	„ „ yellow
$COGrI$	Non tinged green
$COgrI$	„ „ yellow
$COGRi$	Black (green hypostatic)
$COgRi$	„ (yellow hypostatic)
$COGri$	Brown (with green tinge)
$COgri$	„ (without green tinge)
$Cogri$	Reddish brown
$cOgri$	Buff

The genetic composition of the parental plants of the cross between "Haiiro" and "Tanishi" would be $CCOOGGrrii$ and $CCOOggRRII$ respectively. The F_1 plant is therefore heterozygous to three genes Gg Rr and Ii but homozygous to C and O. The different phenotypes appeared in F_2 are due to the recombination of these genes. Thus:

	Blue tinged	Black	Non tinged	Brown	Total
Yellow	$COgRI$ 9	$COgRi$ 3	$COgrI$ 3	$COgri$ 1	16
Green	$COGRI$ 27	$COGRi$ 9	$COGrI$ 9	$COGri$ 3	48
	Anthocyanin present 48		Anthocyanin absent 16		64

In blacks, yellow, green or brown is completely covered, but in brown green colour is visible, hence blue tinged greens, blue tinged yellows, non tinged greens, non tinged yellows, blacks and browns arise by the ratio $27 : 9 : 9 : 3 : 12 : 4$. If we denote above phenotypes by *B.T.G.*, *B.T.Y.*, *G*, *Y*, *Bl*, and *Br.* respectively, the following segregation is expected in the *F*₃ generation.

F_2 plant.			Segregation in F_3	Ratio.
B.T.G.	*GGRRH*	1	*B.T.G.*	Const.
,,	*GGRRh*	2	*B.T.G. : Bl.*	$3 : 1$
,,	*GGRrH*	2	*B.T.G. : G.*	$3 : 1$
,,	*GGRrh*	4	*B.T.G. : G : Bl : Br.*	$9 : 3 : 3 : 1$
,,	*GgRRH*	2	*B.T.G. : B.T.Y.*	$3 : 1$
,,	*GgRRh*	4	*B.T.G. : B.T.Y. : Bl.*	$9 : 3 : 4$
,,	*GgRrH*	4	*B.T.G. : B.T.Y. : Y*	$9 : 3 : 3 : 1$
,,	*GgRrh*	8	*B.T.G. : G. : B.T.Y. : Y : Bl : Br.*	$27 : 9 : 9 : 3 : 12 : 4$
Bl.	*GGRRh*	1	*Bl.*	Const.
,,	*GGRrh*	2	*Bl : Br.*	$3 : 1$
,,	*GgRRh*	2	*Bl.*	Const.
,,	*GgRrh*	4	*Bl. : Br.*	$3 : 1 \ (12 : 4)$
,,	*ggRRh*	1	*Bl*	Const.
,,	*ggRrh*	2	*Bl. : Br.*	$3 : 1$
G	*GGrrH*	1	*G*	Const.
,,	*GGrrh*	2	*G : Br.*	$3 : 1$
,,	*GgrrH*	2	*G : Y*	$3 : 1$
,,	*Ggrrh*	4	*G : Y : Br.*	$9 : 3 : 4$
B T Y	*ggRRH*	1	*B.T.Y.*	Const.
,,	*ggRRh*	2	*B T Y. : Bl.*	$3 : 1$
,,	*ggRrH*	2	*B.T Y : Y*	$3 : 1$
,,	*ggRrh*	4	*B.T Y : Bl. : Y : Br*	$9 : 3 : 3 : 1$
Br	*GGrrh*	1	*Br.*	Const.
,,	*Ggrrh*	2	*Br (greenish) : Br.*	$3 : 1$
,,	*ggrrh*	1	*Br.*	Const.
Y.	*ggrrH*	1	*Y.*	Const.
,,	*ggrrh*	2	*Y. : Br.*	$3 : 1$

The observed data showed a close approximation to the above expectation. See the table below.

TABLE 29.

Showing the result obtained in F_1 of the cross
"Tanishi" × "Haiiro." See also Table 34.

F_2 phenotype	F_2 genotype	No. of families observed	expected	difference
B.T.B.	GGRRII	—	0.594	
	GGRRIi	2	1.187	
	GGRrII	1	1.187	
	GGRrIi	3	2.375	
	GgRRII	3	1.187	
	GgRRIi	3	2.375	
	GgRrII	1	2.375	
	GgRrIi	1	1.751	
		17	16.031	+0.969
Bl.	GGRRii ⎫ GgRRii ⎬ ggRRii ⎭	1	2.375	
	GGRrii ⎫ GgRrii ⎬ ggRrii ⎭	6	4.751	
		7	7.126	−0.126
G.	GGrrII	—	0.594	
	GGrrIi	2	1.187	
	GgrrII	1	1.187	
	GgrrIi	3	2.375	
		6	5.343	+0.657
B.T.Y.	ggRRII	1	0.594	
	ggRRIi	1	1.187	
	ggRrII	1	1.187	
	ggRrIi	3	2.375	
		6	5.343	+0.657
Y.	ggrrII	—	0.594	
	ggrrIi	—	1.187	
		—	1.1781	−1.178

F_2 phenotype	F_2 genotype	no. of families observed	expected	difference
Br	GGrrii	1	0.594	
	Ggrrii	1	1.187	
	ggrrii	--	0.594	
		2	2.375	−0.375

In the case of the cross "Waremame" × "Achmmri" in which buff and black are crossed, two pairs of genes are concerned in the formation of four types of seed coat, i.e., self black, imperfect black, brown and buff. If we let a pair of genes C and c stand for the chromogens, imperfect black was found to carry no C, in spite of the fact that the ground-colour appeared to be brown, as already mentioned, hence we may assume that the full development of the deep purple anthocyanin pigment is only possible by the presence of C and R. The gene for the formation of the chromogenic substance may therefore have a simultaneous action on the formation of brown and self black from the same chromogenic substance. Here the gene G is not concerned. The parental plants may have the following genotypic composition with respect to the colour of the seed coat:

| Self black | $CCOORRiigg$ |
| Buff | $ccOOrriigg$ |

The F_1 plant is heterozygous to C and R, and in F_2 we should expect the following families:

Self black	$CCRR$	1	Black	const.
,,	$CCRr$	2	Black : brown	3 : 1
,,	$CcRR$	2	Black : imperf. black	3 : 1
Self black	$CcRr$	4	Black : imperf. black : brown : buff	9 : 3 : 3 : 1
Imperfect black	$ccRR$	1	Imperf. black	Const.
,,	$ccRr$	2	Imperf. black : buff	3 : 1
Brown	$CCrr$	1	Brown	Const.
,,	$Ccrr$	2	Brown : buff	3 : 1
Buff	$ccrr$	1	Buff	Const.

The actual numbers observed are as follows.

TABLE 30.

Showing the result obtained in F_3 of the cross " Waremame " $\times$ " Achimuri "

See also Table 35

F_2 plant phenotype	genotype	no. of families		diff. (ob.—exp.)
		observed	expected	
Black	$CCRR$	3	2.875	+0.125
,,	$CcRR$	8	5.750	+2.250
,,	$CCRr$	6	5.750	+0.250
,,	$CcRr$	15	11.500	+3.500
Black imp.	$ccRR$	2	2.875	−0.875
,,	$ccRr$	6	5.750	+0.250
Brown	$CCrr$	3	2.875	+0.125
,,	$CCrr$	3	5.750	−2.750
Buff	$ccrr$	0	2.875	−2.875

The different colour types of the soy bean seed coat so far concerned constitute the following series when they are arranged according to dominancy : blue tinged green>blue tinged yellow>green>yellow>black>imperfect black>browns (lighter brown>deeper brown)>buff.

It is of interest to compare the case of the soy bean to that of the Adzuki bean which have been investigated by TAKAHASHI and FUKUYAMA (1917)[1]. They have shown that the different colour types behaved strictly in accordance with Mendelian principle as in the case with the soy bean. The different types can be arranged, according to dominancy, as follows: Blue black>black>black flecked (" Yogore ")>black flecked red greenish grey> deep buff (" Cha ")>red (self)>red-eyed white>white

The test for the chromogenic substances already remarked (see Table 8) shows that the chromogenic substance P and F are present in the green, unripe beans of all the coloured types but absent in white which is a " warm buff" according to the nomenclature by RIDGWAY. White is the most recessive character in the series. In the case of the soy bean, the types which show very little chromogen content are green and yellow which are dominant over the types rich in the chromogenic substance. The difference in the genetical

1. TAKAHASHI, Y. and FUKUYAMA, J. Morphological and Genetic Studies on the Adzuki-bean. Hokkaido Agric. Exp. Station, Japan. Report 7, pp. 161 (in Japanese).

behavior of the chromogen containing types in the two species of plants is due to the presence and absence of an inhibitor. The authors showed that in the cross between buff and white, the F_2 seed was buff and segregated in F_3 buffs, reds and whites by a rate $9:3:4$. While the cross between deep buff and white gave deep buff in F_1 (F_2 seed) and deep buffs, buffs, reds and whites in the F_3 generation by the ratio $27:9:12:16$. Thus we see that the deep buff differs from buff by a single factor-difference and buff and red also by another factor pair. We see therefore that the inhibitor is also present in that case but differs from that of the soy bean in such a way that the inhibitor in the Adzuki-bean inhibits the formation of reddish brown pigment from the chromogenic substance but the action does not seem to extend over the formation of the chromogenic substance, while in the case of the soy bean, the inhibitor inhibits the formation of the chromogenic substance, so that no chromogenic reaction can be observed in the green and yellow. In the buffs, the chromogenic substance can readily be directed and if another gene, a chromophelein is added to it, the deep buff is produced.

The writer was able to test the chromogenic substance by the material which was kindly furnished to him through the courtesy of Mr. FUKUYAMA. Fully ripened deep buff and buff were found to be rich in the chromogenic substance P. The green unripe beans born on the plants raised from the same material in the next year also gave the similar result.

In order to compare the genotypic compositions of the types of Adzuki and those of the soy beans, it is convenient to change the designations used by the authors to those proposed in the present paper. They gave RHf for buff, Rhf for red, and rhf for white in which R is the gene for red, H an inhibitor and F the gene for buff. We assume that the genes for the red pigment are C and o and by the action of an inhibitor I results in the formation of buff. The gene I only inhibits the action of o but that of C is left free. We have some data for believing that the reddish brown pigment of the Adzuki-bean is the oxidation product of the chromogenic substance. The pigment is insoluble in strong acids, but readily soluble in water and especially in weak alkalies yielding a deep wine red colour which becomes yellow by acid. The alkaline pigment is insoluble in ether and acetic ether but in a weak acid solution, sparingly soluble in ether, and by evaporating

the solvent yields an amorphous reddish brown pigment. The pigment may be precipitated from aqueous solution by lead acetate.

Consequently the gene *I* seems to inhibit the action of oxidizing agency acting on the chromogenic substance. The above mentioned relation which exists in buff and red seems to be analogous to that of the case of the dominant white in *Primula sinensis*. According to Keeble and Armstrong (1912)[1], Keeble, Armstrong and Jones (1913)[2] and Keeble and Miss Pellow (1910)[3] certain dominant whites contain chromogen, which occurs in the recessive white in an extremely slight amount and the inhibitory substance which obscures the peroxidase reaction is present in the former. The buff coloured seed coat of the Adzuki-bean can be considered somewhat analogous to the dominant white in the flower of *Primula* and the white to the recessive white. The colour of buff and white in the seed coat differ slightly from each other. The peroxidase reaction in the seed coat was also examined and an indication to the similar relation that was observed in the flower of *Primula sinensis* was obtained. In the epidermis of the seed coat in which the pigment is confined, the peroxidase reaction was extremely slight in the unripe green seed of buff and deep buff whereas in the white, very distinct. The observation was repeatedly made with the material taken at the different stage of maturity. The section was placed under the cover glass with the alcoholic solution of benzidine or alpha naphtol with a dilute solution of hydrogen peroxide. In this manner, the direct oxidase has failed to be detected in all cases.

The reddish brown in the soy bean (such as "Aka-nedzumine") corresponds with red in the Adzuki-bean. The gene *O* which modifies the reddish brown to brown in the soy bean corresponds with the gene *I* in the other, inasmuch as they suppress the formation of reddish-brown, oxidation product of the chromogenic substance, though they differ in the manner toward the formation of the chromogenic substance as already mentioned. The genetic composition of the different self coloured types in both species can be expressed by the same designations in the following manner :

1, Keeble, F. and Armstrong, E. F., Loc. cit.

2. Keeble, F., Armstrong, E. F., and Jones, W. N., The Formation of the Anthocyan Pigments of Plants. 6. Proc. Roy. Soc. London, B. 87 : 113, 1813.

3. Keeble F. and Pellow, C., White Flowered Varieties of Primula sinensus. Jour. Genetics. 1 : 1, 1910.

	Soy bean		Adzuki-bean
Buff	*cOrig*	White	*corig* (*rfh*)
Reddish brown	*Corig*	Red	*Corig* (*Rfh*)
Brown	*COrig COriG*	Buff	*CorIg* (*RfH*)
		Deep buff	*COrIg* (*RFH*)
Black	*CORig* etc.	Black	*CorIg* (*RFhMC*)
Yellow	*COrIg* etc.		
Green	*COrIG* etc.	Green	*COrIG* etc.

Also, in the seed coat of *Phaseolus vulgaris*, *Phaseolus multiflorus*[1] *Pisum sativum*[2], *Vigna unguiculta* and *Vigna sinensis*[3], the coloured types which are due to anthocyanin pigments are dominant over those which are due to phlobaphene pigments and the latter are dominant over white types. In *Pisum*, the well known work of MENDEL has already shown that the brown coloured pea is a simple dominant over the colourless one. LOCK enumerated the genes concerning the colour of the testa as follows ; (1) greyish or brownish pigmentation as opposed to the absent (white) (*C*) (*c*), (2) purple spotted of bright purple spots as opposed to very faint or absence of the character (*S*) (*s*), (3) the presence of maple character. Mapling or mottling of a rich brown colour as opposed to the absence of the character (*M*) (*m*).

1.　Lock. R. H., Studies in Plant Breeding in the Tropics.　Ann. Roy. Bot. Gard. Peradeniya. 3 : 95. 1906.　Shull. G. H., Some Latent Characters in White Bean.　Science. N. S. 25 : 828, 1907. —Shull. A New Mendelian Ratio and Several Types of Latency.　Amer. Nat. 42 : 433, 1908.— Tschermak, v. E., Weitere Beiträge ueber Verschiedenwertigkeit der Merkmarle bei Kreuzung von Erbsen u. Bohnen Zeit f. d. l. Versuch. Osterreich, 1901, 611.—Tschermak, Weitere Kreutzungs-studien an Erbsen, Levkojen und Bohnen.　Ibid. 1904, 533.—Tschermak, Bastardierungsversuche an Levkojen, Erbsen, und Bohnen mit Rücksicht auf der Faktorenlehre. Zeit.f. induk. u. Vererb. 7 : 81. 1912.　Emerson, R. A., Inheritance of Color in the Seeds of the Common Bean, :Phaseolus vulgaris. Ann. Report Nebraska Exp. Station 22 ; 67, 1909.—Lundberg, J. and Akerman, A , The Colour of the Seed in the Descendants of A Natural Hybrid of Two Varieties of Phaseolus vulgaries. Sveriges Utsadesforeinge Tidskrift. 27 : 115, 1917.　(cited in Internat. Review of Sc. and Pract. of Agric. 8 : Entry 1013, 1917.)

2.　Lock, R. H., The Present Stage of Knowledge of Heredity in Pisum. Ann. Roy. Bot. Peradeniya. 4 : 93. 1908.　Mendel. G., Versuche under Pflanzenhybriden. Verhand. Naturforsch. Verein in Brünn. 10 : 1865.—White, O. F., Researches on the 35 Factors Determining the various Characters of the Genus Pisum, Jour. Agric. Research. 11 : 166, 1917.

3.　Spillman, W. J., Inheritance of the " Eye " in Vigna. Amer. Nat. 45 : 513. 1911.—Spill-man, Color Correlation in Cowpeas.　Science N. S. 38 : 302, 1913.—Harland, S. C., Inheritance of certain characters in the Cowpas (Vigna Sinensis)　Jour. Genet. 8 . 101, 1919.

In certain varieties of *Phaseolus vulgaris*, TSCHERMAK (1912) showed that the coloured seed coat was dominant over white, and among coloured types the relation, black>violet>brown was established. SHULL (1908) also found in the same plant, purple, brown, yellowish-brown and yellow were dominant over white. He proposed the following genetic composition for the different self coloured types :

Brown and yellow	Pbm
Black	PBm
White	pBM

in which P is a gene for the pigment, B the modifier of the pigment, and M the mottling gene. P may correspond with CO or C and B with R in our case.

In dealing with the colour of patterns of the seed coat of *Vigna unguiculata* and *Vigna sinensis* SPILLMAN (1913) and HARLAND (1919) respectively found that the solid coloured types were dominant over the mottled and less coloured ones. The latter author showed also that black was dominant over brown, and brown over red. The brown was completely dominant over red in F_1 and brown, maroon, and red arose in the F_2 by the ratio $12:3:1$. These colours are of the phlobaphene nature and no anthocyanin is concerned except black. The genetical behaviour of the phlobaphene colour types in this plant is quite similar to that which we have seen in Adzuki and soy beans. In all these cases the more intense reddish-brown is recessive to less intensely coloured types.

In *Zea Mays*, EAST and HAYES (1911)[1] showed that the dark-red pericarp was a simple dominant over white. The colour of the pericarp is due to the pigment belonging to the phlobaphene group. The purple and red aleurone colours are due to anthocyanins. The formation of the anthocyanin pigment in the aleurone cells is in certain cases, governed by the genes (C. R, P of EAST and HAYES, C, R, A, Pr. of EMERSON) which are apparently similar in kind as those met in the case of *Lathyrus*, *Antirrhinum* and *Oryza*.

1. EAST. E. M. and HAYES, H. K., Inheritance in Maize. Bull. Conn. Agric. Exp. Station 167, 1911.—EMERSON, R. A., A Fifth Pair of Factors, A a, for Aleurone Color in Maize, and Its Relation to the C c and R r Pairs. Cornell University Agric. Exp. Station Memoir 16, 1918.

Thus we see that the pigment yielding mechanism in the seed coat of different species of plant falls in general under a similar category, particularly in the seed coat of the legumes.

4. DISCUSSION.

To a gene we imply a specific protoplasmic entity which sets up the biochemical apparatus in the sporophytic cells and to the end product of the reaction performed by the mechanism so set up, we refer a character, morphological and physiological. Therefore, even we infer a gene to a character, that gene itself may have no direct relation to the character. A catalyst does not appear in the final product of a chemical reaction, but may alter the velocity of the reaction and sometimes change the position of equilibrium to be attained.

When such agencies or genes are paired forming an allelomorph, and they segregate in a normal way, we can deduce the relation between the character and the gene by the numerical ratio of character that is required by the supposed genetic entities. We disregard the biochemical processes involved in the changes which are set up by the gene to bring about the equilibrim, of which state we perceive the character. Dynamically viewed, however, the possibility is not excluded even in such a case in which a single allelomorphic character-difference is due to more than a factor-difference. Supposing the change $A \rightarrow O$ in which the substance A undergoes certain changes to form the substance O which may be regarded as a single character in the Mendelian sense, such as a purple pigment in a certain organ in the plant. $A \rightarrow O$ reaction would appear to be a single change when the initial and the end product alone is considered, but it may involve the catenary changes $A \rightarrow B \rightarrow C \rightarrow D \rightarrow O$. Such complex changes are likely to occur in most of the biochemical processes like respiration and photosynthesis which seem comparatively simple when the initial substance and the final product alone are considered.

If we consider an imaginary instance in which $A \rightarrow B$, $B \rightarrow C$, $C \rightarrow D$, and $D \rightarrow O$ reactions are involved in a whole change $A \rightarrow O$, and these separate changes are governed by the respective genetic entities, yet they are not

separable at the time of synapsis. The character which is due to the end
product of the final change, therefore would appear as due also to a single
genetic entity. Supposing that the purple anthocyanin is produced by $C \rightarrow R \rightarrow P$
changes and three separate genes are actually taking part to bring about
complex chemical changes. But if these genes are linked, or so to say, form
a complex, and do not separate in gametogenesis, they may well be considered
as a single entity and can be substituted by a single designation to express
the genetic entities to a given character. When they separate from the complex
by any cause, a supposed single unit character would appear to be constituted
by more than a single gene.

The separation of genes from the complex may take place either by
hybridization or by unknown internal causes, and of the latter cases, we call
mutation.

It is a comparatively simple matter to determine the number of genes
concerned with given characters by hybridization experiments when the
contrasting characters are distinct and the segregation in the offspring of the
hybrid is sharply defined. But it is extremely difficult to interpret those
genes in terms of biochemistry or physiology. We are likely to fall into the
danger of providing a superficial analogy and drawing sweeping conclusion by
confusion of the genetical data to those of physiology.

In the case of the formation of anthocyanin and phlobaphene pigments
in the plants studied, the genes C, O, R and P appear to govern certain
groups of biochemical reactions in the sporophytic cells more or less in a
distinct manner, yet we must have great reserve in referring these genes to
any physiological factors. It is true that the peroxidase coexists with the
pigment, and the normal oxygen relation is essential to the formation of the
pigment, but these facts prove in no way to allow us in interpreting the
complementary gene of the colour producing system in plant is exclusively
relating to peroxidase. Even in the case of the formation of brown and
reddish brown pigments, in which the oxidation of the chromogenic substance
is an essential change, the direct inference of the gene to peroxidase or
oxidase may deserve serious consideration.

The formation of brown plant-pigments (phlobaphenes) resembles, as we
have already seen in the preceding pages, that of melanin pigments in animals

in some respects. Certain authors go so far as to regard the brownish pigments in the seed coat of the legumes as a sort of plant melaninic pigment.[1]

WRIGHT (1917)[2], proposed an hypothesis regarding the colour inheritance in Mammals. He proposes first, that melanin is produced by the oxidation of certain products of protein metabolism by the action of specific enzymes; second, that this reaction takes place in the cytoplasm of cells probably by enzymes secreted by the nucleus; third, that various chromogens are used, the particular ones oxidized depending on the characters of the enzymes present, and finally that hereditary difference in colour are due to hereditary differences in the enzyme element of the reaction. It is supposed that color depends on the rates of production or of potency of two enzymes. Enzyme I is essential to the production of any colour, but by itself only produces yellow. Enzyme II is supplementary to enzyme I, producing no effect by itself. The compound enzyme I—II is also more efficient than enzyme I in another way. It produces sepia pigment even when enzyme I is at too low a potency to produce any yellow by itself. Above the level at which enzyme I produces effects, the enzyme I and I—II, complete the oxidation of chromogen.

Regarding the place of the enzyme reaction to the chromogenic substance, his hypothesis may be referred to the view of UNNA (1913)[3] in which he maintained that in the tissue of the animal skin, the plasma is the reduction place (" Reduktionsort ") and the nucleus, the oxidation place (" Sauerstoffort "). In plants, however, SCHNEIDER (1914)[4] could not establish UNNA's view.[5]

If the mitochondria is the seat of the pigment synthesis as GUILLIERMOND

1. MANN, A., Coloration of the Seed Coat of Cowpeas. Jour. Agric. Research. 2 : 33, 1914. The substances known as " Phytomelan " are, however, different from phlobaphenes. See DAFERT, F. W. and MIKLAUZ, R., Untersuchungen ueber die kohleähnliche Masse der Kompositen. I. Denkschr. d. Kais. Akad. d. Wien. Bd. 87, 1911. Cited in MOLISCH, H., Mikrochemie der Pflanze. p. 319, 1913.

2. WRIGHT, S., Color Inheritance in Mammals. Jour. of Heredity. 8 : 221, 1917.

3. UNNA, P. G., Biochemie der Haut. Jena. 1913.

4. SCHNEIDER, H., Ueber die Unnaschen Methoden zur Feststellung von Sauerstoff-und Reduktion-Orten u. ihre Anwendung auf Pflanzliche Objekte-Benzidin als Reagens auf Verholzung Zeitsch. f. wiss. Mikro. Tech. 31 : 51, 1914. a.—SCHNEIDER. Neue Studien zur Darstellung der Reduktions u. Sauerstofforte der Pflanzenzelle. Ibid. 478. 1914. b.

5. Cf. OSTERHAUT, W. J. V., The Role of the Nucleus in Oxidation Science. N. S. 46 : 367, 1917.

and others[1] have reported, the reaction place seems to be chiefly located in the cytoplasm. All the genes must be retained in the nuclear substance of the sporophytic cell in some latent state, and the reaction done by them in the cell to produce the pigment must be realized by some sort of substances derived from the nucleus. The actual relation between the substance of genes in the nucleus and the mechanism in the cytoplasm conditioned by the former, is known to none of us. It seems therefore altogether premature to speculate, as certain biologists might propose, that the gene itself is the enzyme. Even in the pure chemical field, we do not know as yet the exact chemical nature and the mode of action of enzymes.

III Summary and Conclusion.

In a number of species of plants examined, two groups of pigments anthocyanins and the reddish brown pigments (phlobaphenes) can be traced to the chromogenic substances, previous to their formation. In certain cases, both of the pigments can be formed from the same chromogenic substance by the action of various complementary pigment-yielding agencies.

The chromogenic substances can be identified to two groups of allied substances, one of which is designated as the chromogenic substance F which includes the glucoside of certain flavones and flavonols, and the other, the chromogenic substance P of which the chemical nature is yet unknown.

Evidence is given to show that certain brown and reddish brown pigments (phlobaphenes) are the oxidation products of the chromogenic substance P and F.

Certain anthocyanins are completely decolorized by the action of oxidizing enzymes.

Certain flavones, flavonols and their glucosides yield a characteristic oxidation colour by the action of oxidizing enzymes.

    1. GUILLIERMOND, A., Sur la formation de l'anthocyane au sein des mitochondries. Comp. Rend. Acad. Sci. Paris. 156 : 1921. 1913.—GUILLIERMOND, Nouvelles recherches cytologiques sur la formation des pigments anthocyaniques. Ibid, 157 : 1000, 1913.—GUILLIERMOND, Quelques observations cytologiques sur la mode de formation des pigments anthocyaniques dans les fleurs. Ibid. 161 : 494, 1915.—GUILLIERMOND, Recherches cytologiques sur la formation des pigments anthocyaniques. Rev. Gene. Bot. France. 25 : 295, 1914.—MOREAUX, F., Loc. cit.—MIRANDE, M., Observation sur le vivant de la formation cytologique de l' anthocyanine. Comp. Rend. Acad. Sci. Paris. 163 : 368, 1916.

The anthocyanin pigment is the reduction product of the chromogenic substance when the chromogenic substance F alone is concerned, but the other possibilities are not excluded when the chromogenic substance P is concerned.

When the complete system is laid down in the sporophytic cells by the combination of the separate components which are retained by the specific genetic entities, anthocyanin pigment is formed in the awn, and glumes of *Oryza sativa*. Hence by a proper crossing, the awn of the hybrid plant between two races which lack the pigment, forms anthocyanin.

A linkage relation was observed between the purple colour in the awn and the reddish brown colour in the testa in the varieties of *Oryza sativa* studied.

The brown pigment of the awn of *Oryza* is due chiefly to the oxidation product of the chromogenic substance F, and that of the testa is due chiefly to that of the chromogenic substance P.

The coloured stigma, purple awn, paleas, and striped leaf-sheath which are due to the presence of anthocyanin are inherited in a group, and in the paleas, the solid purple is linked with the brown pigment which is formed at the underlying tissue of the same organ, while the localized purple repells the latter.

The brown and reddish brown pigments and the purple anthocyanin formed in the seed coat of *Glycine soja* are derived chiefly from the same chromogenic substance belonging to the group of the chromogenic substance P.

The formation of these pigments as well as the chromogenic substance is entirely or partially suppressed by the action of dominant inhibitors.

Certain genetic phenomena relating to the colours of the seed coat are studied. The following is the list of characters studied, arranged according to dominancy in the ascending order. Blue tinged green > blue tinged yellow > green > yellow > black > brown (lighter brown > reddish brown) > buff.

Acknowledgement.

TABLE 31.

Showing the result obtained in F_3 of the cross
" Daikkoto " × " Togo."

F_3 family no.	Awn of F_2 plant	Red	Brown	Faint yellow	Total
14	Brown	36	—	—	36
29	,,	96	—	—	96
38	,,	106	—	—	106
4	,,	15	—	9	24
9	,,	21	—	10	31
19	,,	15	—	7	22
21	,,	16	—	21	67
33	,,	49	—	11	63
35	,,	76	—	27	103
31	,,	57	—	21	78
2	,,	37	29	—	57
6	,,	19	2	—	21
10	,,	63	24	—	87
12	,,	47	18	—	65
16	,,	65	31	—	96
17	,,	46	20	—	66
30	,,	20	9	(1)	30
32	,,	75	22	—	97
35	,,	16	10	—	26
34	,,	48	22	—	70
3	,,	35	15	14	64
7	,,	49	15	32	96
8	,,	52	17	23	92

F_4 family no.	Awn of F_2 plant	Red	Brown	Faint yellow	Total
11	Brown	15	11	16	75
15	,,	33	15	16	64
18	,,	33	10	15	58
20	,,	10	11	4	25
22	,,	28	15	20	63
23	,,	30	19	13	62
25	,,	19	10	5	34
26	,,	55	18	22	98
28	,,	11	6	16	66
1	.	—	47	17	64
13	,,	—	43	18	64
21	,,	—	64		64
37	,,	—	69	—	69
39	Faint Yellow		—	104	104
40	,,		—	63	63
41	,,	—	—	89	89
42	,,	—	—	63	63
43	,,	—	—	66	66
44	,,	—	—	67	67
45	,,	—	—	33	33
46	,,	—	—	98	98
47	,,	—	—	98	95
48	,,	—	—	101	101
49	,,	—	—	97	97
50	,,	—	—	31	31

TABLE 32.

Showing the result obtained in F_3 of the cross

" Kurafusagi " × " Nagoyashiro "

F_3 family no.	Awn of F_2 plant	Red	Brown	Faint Yellow	Total
31	Brown	61	—	—	61
42	,,	91	—	—	91
41	,,	95	—	—	95
45	,,	62	—	—	62

F_3 family no.	Awn of F_2 plant	Red	Brown	Faint yellow	Total
80	Brown	57	—	—	57
82	,,	100	—	—	100
84	,,	96	—	—	96
88	,,	63	—	—	63
2	,,	67	29	(1)	97
3	,,	48	13	(1)	62
22	,,	49	16	—	65
23	,,	67	28	(1)	96
36	,,	67	30	—	97
49	,,	67	32	—	99
57	,,	66	27	—	93
58	,,	51	21	—	72
60	,,	75	25	—	100
62	.	56	13	—	69
64	,,	45	15	—	60
69	,,	66	31	—	97
73	,,	65	23	—	88
74	,,	75	18	—	93
77	,,	68	29	—	97
83	,,	74	17	—	91
86	,,	33	13	—	46
21	,,	23	8	—	31
15	,,	44	(1)	15	60
32	,,	46	—	16	62
63	,,	19	—	11	30
85	,,	47	—	18	65
89	,,	51	—	12	63
91	,,	28	—	4	32
93	,,	28	—	5	33
94	,,	30	—	4	34
97	,,	25	—	11	36
98	,,	50	—	12	62
102	,,	71	—	13	84
103	,,	67	—	26	93
105	,,	72	—	25	97
1	,,	27	22	11	60
5	,,	32	6	24	62
10	,,	38	22	18	78

F_3 family no.	Awn of F_2 plant	Red	Brown	Faint yellow	Total
13	Brown	16	21	33	100
18	„	50	18	28	96
19	„	55	13	31	99
24	„	10	5	3	18
25	„	19	23	26	98
27	„	9	2	5	16
29	„	25	12	24	61
33	„	43	8	16	67
34	„	19	23	29	101
35	„	62	12	22	96
39	„	42	21	24	87
41	„	43	24	26	93
43	„	33	14	16	63
50	„	56	19	17	92
52	„	19	8	6	33
55	„	40	14	17	71
59	„	43	20	25	78
65	„	29	14	22	65
75	„	34	10	22	66
76	„	34	16	15	65
79	„	32	15	14	61
87	„	48	21	26	95
11	„	58	19	24	101
92	„	64	8	19	91
107	„	42	11	16	69
108	„	56	13	32	101
109	„	54	18	21	96
110	„	27	13	25	65
4	„	—	41	14	58
6	„	—	62	22	84
7	„	—	72	18	90
9	„	—	26	10	36
28	„	—	68	25	93
30	„	—	73	20	93
37	„	—	77	21	98
38	„	—	76	23	99
44	„	—	29	11	40
70	„	—	67	28	95

F_3 family no.	Awn of F_2 plant	Red	Brown	Faint yellow	Total
71	Brown	—	78	23	101
78	„	—	41	20	61
81	„	—	38	15	53
90	„	—	63	33	96
56	„	—	34	9	45
8	„	—	96	—	96
12	„	—	13	—	13
14	„	—	28	—	28
40	„		63	—	63
47	„	—	57	—	57
71	„	—	91	—	91
111	Faint yellow	—		64	64
112	„	—	—	33	33
113	„	—	—	63	63
111	„	—	—	99	99
115	„	—	—	98	98
116	„	—	—	101	101
117	„	—	—	99	99
118	„	—	—	98	98
119	„	—	—	64	64
120	„			99	99
121	„	—		87	87
122	„	—	—	100	100
123	„	—	—	94	94
124	„		—	33	33
125	„		—	92	92
126	„	—	—	85	85
127	„	—	—	61	61
128	„	—	—	97	97
129	„	—	—	95	95
130	„	—	—	92	92
131	„	—	—	97	97
132	„	—	—	86	86
133	„	—	—	96	96
134	„	—	—	64	64
135	„	—		65	65
136	„	—	—	62	62
137	„		—	80	80

F_3 family no.	Awn of F_2 plant	Red	Brown	Faint yellow	Total
138	Faint yellow			64	64
139	,,	—	—	33	33
140	,,		—	34	34
141	,,		—	34	34
142	,,	—	—	38	38

TABLE 33.

Showing the result obtained in F_3 of the cross

" Hanbun-nento " × " Genroku-mochi "

F_3 family no.	Paleas of F_2 plant	Awn purple		Awn red		Totals
		paleas self P	paleas loc. P	paleas brown	paleas f. yellow	
2	Self purple	58	16		—	74
4	,,	70	21	—	—	91
18	,,	75	21	—	—	96
21	,,	72	22	—	—	94
25	,,	54	11	—	—	65
30	,,	74	20	—	—	94
42	,,	51	12	—	—	63
63	,,	6	2	—	—	8
66	,,	14	1	—	—	15
68	,,	26	8	—	—	34
10	,,	74	—	21	—	95
13	,,	62	—	34	—	96
15	,,	55	—	12	—	67
22	,,	78	—	20	—	98
37	,,	61	—	21	1	82
45	,,	65	—	21	—	86
47	,,	64	—	32	—	96
48	,,	71	—	27	—	98
56	,,	25	—	9	—	34
16	Local. purple		48	—	15	63
20	,,	—	69	—	19	88
23	,,	—	62	—	37 (2)*	101

* Not recorded.

F_3 family no.	Paleas of F_2 Plant	Awn purple		Awn red		Totals
		Paleas self P.	Paleas loc. P.	paleas brown	paleas f. yellow	
27	Local. Purple	—	44	—	17	61
31	,,	—	57	—	32	89
39	,,	—	70	—	26	96
44	,,	—	77	—	27	104
49	,,	—	77	—	23	100
53	,.	—	25	—	8	33
57	,,	—	73	—	5	78
58	,.	—	20	—	11	31
59	,,	—	59	—	11	73
64	,,	—	40	—	29	69
21	,,	—	34	—	—	34
36	,.	—	89	—	—	89
44	,,	—	95	—	—	95
54	,,	—	97	—	—	97
64	,.	—	19	—	—	19
67	,.	—	30	—	—	30
6	,,	—	34	—	—	34
3	Self purple	64	5	12	2	83
5	,,	57	19	14	5	95
11	,,	54	17	22	5	98
19	,.	53	16	27	6	102
26	,,	58	19	15	10	102
28	,,	54	15	19	6	94
29	,,	65	14	17	3	99
31	,,	58	16	14	8	96
35	,,	62	13	19	5	99
46	,,	46	22	22	5	95
50	,,	31	8	16	4	62
51	,,	37	16	11	1	68
55	,,	39	11	7	6	63
65	,,	19	4	5	6	34
69	,.	17	10	7	—	34
8	Brown	—	—	72	23	95
9	,,	—	—	12	13	55
32	,,	—	—	58	39	97
33	,,	—	—	69	27	96
43	,,	—	—	59	32	91

F_3 family no.	Paleas of F_2 plant	Awn purple		Awn red		Totals
		paleas self. P.	paleas loc. P.	paleas brown	paleas t yellow	
62	Self purple	23	—	—	—	23
12	Brown	—	.	102	—	1:2
17	"	—	—	78	—	78
40	"	—	—	31	—	31
1	Faint yellow	—	—	...	101	101
7	"	—	.	—	81	81
60	"	—	—	—	78	78
38	"	—	—	—	68	68

TABLE 34.

Showing the result obtained in F_3 of the cross
"Haiiro" × "Tanishi".

F_3 family no.	Colour of seed coat of F_3 seed	Blue tinged		Non tinged		Black	Brown	Totals
		green	yellow	green	yellow			
14	Blue tin. gr.	1	—	.	—	1	—	2
20	"	5	—	—	—	1	—	6
		6	—	—	—		—	8
		6.0	—			2.0		
19	"	59	—	17	—	—	—	76
	.	59		17				76
		57.0		19.0				
23	"	18	—	12	—	2	2	34
1	"	36	—	13	—	—	1	50
11	"	33	—	8	—	1	—	42
		87		33		3	3	126
		70.875		23.625		23.625	7.875	
2	"	20	7	—	—	—	—	27
22	"	58	19	—	—	—	—	77
24	"	45	11	—	—	—	—	56
		123	37					160
		120.0	40.0					
28	"	41	8	12	6	—	—	67

F_3 family no.	Colour of seed coat of F_3 Seed	Blue tinged		Non tinged		Black	Brown	Totals
		green	yellow	green	yellow			
		41	8	12	6			
		37.688	*12.563*	*12.563*	*4.181*			
9	Blue tin gr.	10	1	—	—	4	—	18
21	,.	29	2	—	—	11	—	42
32	.,	6	4	—	—	8	—	18
		45	10			23		78
		43.675	*14.625*			*19 500*		
1	..	18	5	4	3	5	3	38
15	,.	16	6	2	1	9	3	37
30	..	32	8	3	2	11	2	58
31	.,	39	6	19	2	20	7	84
		96	25	28	8	45	15	217
		91.546	*30.515*	*30.515*	*10.172*	*40 687*	*13 562*	
7	..	40	—	—	—	—	—	40
		40						40
25	..	19	—	—	8	—	—	27
		19			8			
		20.25			*6.75*			
18	,.	35	—	12	—	—	—	47
		35		12				
		35 25		*11.75*				
3	Blue tin. y.	—	58	—	15	16	5	91
5	..	—	35	—	2	14	1	52
8	..	—	26	—	6	4	2	38
			119		23	34	8	184
			103.50		*34 50*	*34 50*	*11.50*	
6	Black	—	—	—	—	5	—	5
						5		5
12	..	—	—	—	—	42	12	54
10	..	—	—	—	—	45	17	62
26	.	—	—	—	—	29	9	38
17	,.	—	—	—	—	24	10	34
27	,.	—	—	—	—	1	1	2
29	.,	—	—	—	—	13	7	20

F_3 family no.	Colour of seed coat of F_3 seed	Blue tinged green	Blue tinged yellow	Non tinged green	Non tinged yellow	Black	Brown	Totals
						154	56	210
						157.50	*52.50*	
35	Green	—	—	9	—	—	9	18
40	,,		—	20	—	—	5	25
				29			14	43
				32.25			*10.75*	
38	,,	—	—	15	2	—	—	17
				15	2			17
				12.75	*4.25*			
31	Green	—	—	20	8	—	6	43
41	,,	—	—	38	14	—	19	71
33	,,	—	—	35	10	—	14	59
				102	32		39	173
				97.308	*32.436*		*43.248*	
36	Brown	—	—	—	—	—	57*	57
37	,,	—	—	—	—	—	21	21

TABLE 35.

Showing the result obtained in F_3 of the cross
" Waremame " × " Achumuri ".

F_3 family no.	Colour of seed coat of F_3 seed.	Black self	Black imperfect	Brown	Buff	Totals
5	Self black	19	—	—	—	19
22	,,	2	—	—	—	2
31	,,	51	—	—	—	51
2	,,	33	9	—	—	42
7	,,	25	9	—	—	34
10	,,	12	5	—	—	17
14	,,	26	15	—	—	41
15	,,	18	9	—	—	27
29	,,	4	1	—	—	5
30	,,	14	4	—	—	18

* 19 with green tinge.

F_3 family no.	Colour of seed coat of F_3 seed.	Black self	Black imperfect	Brown	Buff	Totals
1	Self black	20	7	—	—	27
2	,,	33	—	9	—	12
9	`	4?	—	16	—	56
16	,,	11	—	2	—	13
21	,,	58	—	16	—	74
21	,,	3	—	1	—	4
32	,,	1	—	2	—	3
3	,,	21	9	2	1	33
4	,,	31	4	1?	4	19
6	,,	46	18	19	4	87
8	,,	10	4	4	1	16
11	,,	2?	3	5	2	3?
12	,,	12	4	1	5	22
13	,,	2?	4	10	—	34
18	,,	26	8	10	2	46
19	,,	35	13	13	6	67
20	,,	3	?1	2	—	6
23	,,	1	7	9	1	11
25	,,	23	9	7	3	12
26	,,	24	15	14	3	66
27	,,	26	10	3	3	42
33	,,	33	14	9	7	63
17	Black imperfect	—	26	—	—	26
35	,,	—	27	—	—	27
31	,,	—	14	—	3	17
36	,,	—	35	—	9	44
38	,,	—	26	—	5	31
39	,,	—	39	—	15	54
40	,,	—	4	—	2	6
41	,,	—	5	—	1	6
44	Brown	—	—	34	—	34
46	,,	—	—	6	—	6
47	,,	—	—	7	—	7
28	,,	—	—	4	1	2
43	,,	—	—	29	10	39
45	,,	—	—	29	12	32

EXPLANATION OF PLATE 1

Figures 1–10. The seeds of *Glycine soja* showing the colour of the seed coat. Figures 11–17. The spikelets of *Oryza sativa* showing the colour of the awn, paleas and glume.

Fig. 1. " Waremame ", buff.

Fig. 2. " Achunuri ", solid black with the characteristic local breakings in the epidermis, through which the colourless underlying tissue is shown.

Fig. 3. F_3 seed " Waremame " × " Achunuri ", solid black without breakings in the coloured epidermis.

Fig. 4. F_3 seed " Waremame " × " Achunuri ", " imperfect black ", the ground colour brown.

Fig. 5. F_3 seed " Waremame " × " Achunuri ", brown.

Fig. 6. " Haiiro ", brown with green tinge. The greyish green tinge shown in this figure changes to brown as shown in Fig. 10 when the seed is kept long.

Fig. 7. " Tanishi ", blue tinged yellow.

Fig. 8. F_3 seed " Haiiro " × " Tanishi ", non-tinged green.

Fig. 9. F_3 seed " Haiiro " × " Tanishi " non-tinged yellow.

Fig. 10. F_3 seed " Haiiro " × " Tanishi ", brown.

Fig. 11. " Hanbun-nento ". Early stage in the development of the pigment. The awn red, paleas brown, and glume red.

Fig. 12. Same as Fig. 11. Later stage showing the development of the brown colour in the paleas. The fully riped one is similar to that shown in Fig. 14.

Fig. 13. " Genroku-mochi ", purple localized in the paleas.

Fig. 14. F_3 " Hanbun-nento " × " Genroku-mochi ". Awn red, paleas brown.

Fig. 15–17. F_1 " Hanbun-nento " × " Genroku-mochi " showing the stages in the development of purple pigment in the awn, paleas, and glume. The fully developed stage is shown in Fig. 17.

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POSTSCRIPT

The reference should be made to the following papers which have been received after the manuscript left the writer's hand.

TAKAHASHI, Y. and FUKUYAMA. J., (Morphological and Genetic Studies on the Soy Bean. Hokkaido Agric. Exp. Station Report No. 10, 1919.) reported the results of a number of crosses made between the different varieties grown in Hokkaido, in which certain colour characters of the seed coat are treated. Unfortunately the material is presented without genetical analysis owing to the incompleteness of the data. The following is the main results.

Pale yellow × green gave in F_1, a green seed and segregated in F_2, green and pale yellow by the ratio 3 : 1. In the subsequent generation, however, browns and reds appeared. Brown × pale yellow produced in F_1, a pale yellow seed, and segregated in F_2, 29 pale yellows and 2

reddish brown.   Pale yellow × black produced in F_1, a pale yellowish green seed and in F_2, 20 greens, 20 pale greens, 10 pale yellows, 9 blacks, 2 browns and 4 reddish brown were found. Among greens and pale yellows, 17 and 7 were tinged with black of different shades respectively. Pale green × brown produced a pale green seed in F_1, and in the next generation pale green, yellow, black, and brown appeared by the following numbers: 27, 9, 15, and 5.   Among the first two classes, six of them in each were tinged with blackish shade.   Black × green produced in F_1, a pale yellowish green seed, and in F_2, pale green, green, reddish brown, and black were found.

O. ROSENHEIM (Observations on Anthocyanins. I. The Anthocyanins of the Young Leaves of the Grape Vine.   Biochemical Jour. 14 : 178, 1920.) found certain chromogenic substances in the young leaves of the grape vine which gave an anthocyanin-like coloured substance by heating with hydrochloric acid.   He called them "leuco-anthocyanin".

June, 1920.

1   2   3   4

5   6

7   8   9   10

11   12   13   14   15   16   17

N. Mizushima del.
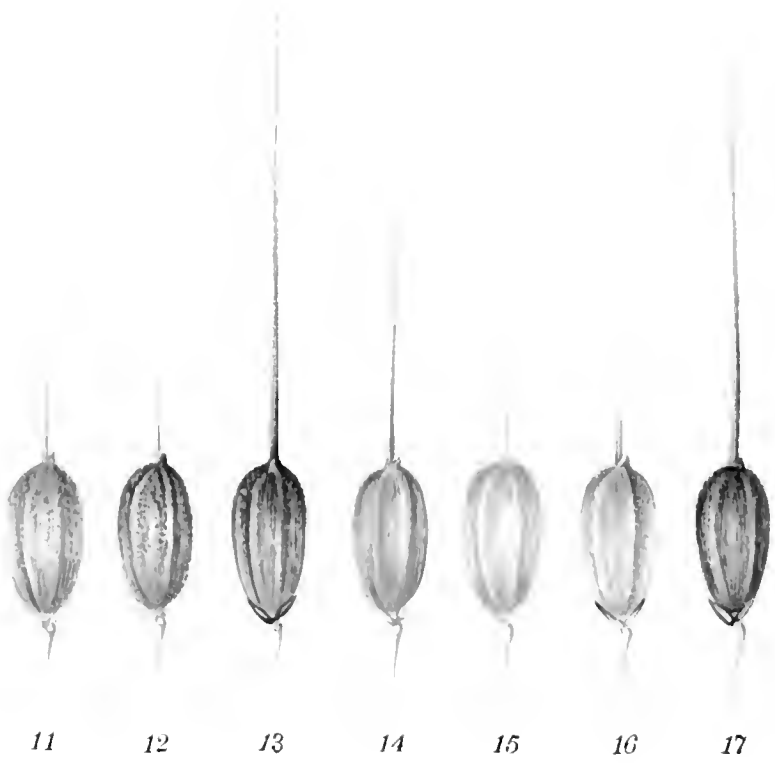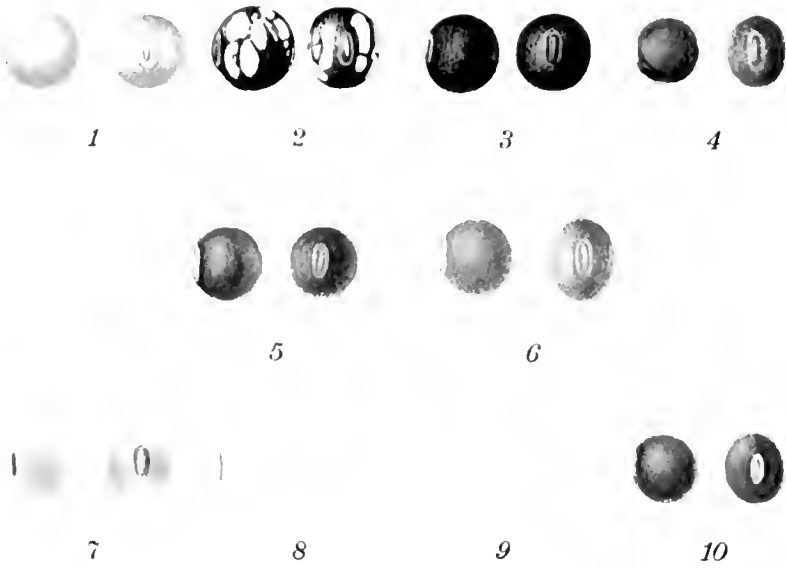
Studies on the Genetics of Flower-Colours in *Portulaca grandiflora.*

By

S. Ikeno.

With Plate II.

CONTENTS.

ERRATA.

Page	Line	
125	22	insert *or successive* after *simultaneous*
126	14	insert *or successive* after *simultaneous*
129	7	read while- II × *orange* instead of white–II × *magenta*.

its flowering begins in June and continues till the end of October. Flowers are beautiful and pretty large; they begin generally to open at about 8 o'clock morning under sunshine, and wither at about the noon of the same day, though in dull weather or in late summer it may continue to open much longer. Each flower is provided with two sepals and five to six petals; there are very numerous slender filaments derived from five stamens by copious ramification; there is one ovary with one style and five to six radiating stigmas, which ripens into a pyxis containing a large number of tiny kidney-shaped seeds. In respect to the colour of the petals there are, so far as I know, five different kinds: they are, namely, white, yellow, orange, flesh-coloured, red, and magenta (s. Pl II), naturally with some fluctuations in their tone. Petals striped in various ways are also found. It may here be remarked that the flower-colour of *Portulaca* is always due to the cell-sap, and never to the chromoplasts.

Materials and Methods.

The breeding experiments of several colour-varieties of this plant were begun in 1915 to study the genetical behaviour of flower-colours. First of all, I have done the self-fertilisation of varieties cultivated in our Botanical Garden in Komaba as well as those obtained from other sources, including white, yellow, orange, red and magenta. Next year seeds got by such selfing were sown. Some of the varieties thus examined were found to segregate, proving themselves to be hybrids; all such ones were rejected, and only those which were found to breed true to their respective types were further cultivated, seeds being taken of course every generation on selfed flowers.[1]

From 1915 I have begun to cross these varieties in various ways, and are now concerned in studying the behaviour of their offspring. Many of these crosses were repeated, and also their offspring were also studied. A variety which bears flesh-coloured flowers was got first in 1917 through the kindness of Dr. I. NAGAI in the Agricultural Experiment Station in Oomagari near Akita; its hybridisation with some other colour-varieties was made in 1918, so that we had in 1920 their F_2-offspring.

[1] On account of poor germination of seeds I have lost the red parent in 1917 and the white-I one in 1918, but I have recovered each of them afterwards by extracting them from their respective hybrids made some years ago, and continue to cultivate them till now.

What makes the breeding of our plant very difficult is the poor germination of seeds. Though each pyxis contains a large number of them many do not come very often to germination; frequently I have met with the cases where even no one from one pyxis had germinated, so that some experiments described in this paper are based on rather few individuals. Many experiments have been carried on to overcome this difficulty. Since, according to my view, the poor germination of seeds would be chiefly due to the difficulty of water passage through seed-coats, one of my methods was to rub out seeds lightly with coarse quartz sand, so as to injure slightly seed-coats and make them easily permeable to water; this treatment has however given no good results whatever. Then I have tried the method of high pressure adopted by DE VRIES:[1] I have used an autoclave-like apparatus specially made for the purpose, and obtained the high pressure by the use of an iron receptacle containing oxygen under high pressure (150 atmospheres when full) instead of an automobile pump, because when the receptacle is connected with the apparatus, the high pressure is attainable instantaneously in the latter. Seeds soaked in water during one night and placed in it were subjected by this means to the pressure of 8 atmospheres or less during 24 hours, and then sown as usual. The following method was made use of in some cases: seeds were first treated with 60% or less concentrated sulphuric acid during 30 minutes, and after repeated washings, they were soaked in water during one night and then sown. The two latter methods above described seem to promote the germination to a certain degree, but not so much as might be wished for.

Seeds from different plants, and later those from different flowers of one individual were sown separately. Since seeds of *Portulaca* are very fine, if we pour down water to seed-pans from above as usual, seeds might often be thrown from one pan to another, thus causing the mixture of seeds from different parents. To avoid this possibility, no water has been given from above: a number of seed-pans were placed in a rectangular vessel of wood, 180 cm. long to 90 cm. wide and 10 cm. deep, partly filled with water, so that the latter may go up gradually.

My study on some of the crosses came already to a certain definite end, and I like to publish here its results, because they will, as I think, enable

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[1] *Bot. Gaz.* Vol. 59, 1915, pp. 192–193.

us clearly to understand the genotypic constitution of all colour-varieties used in my experiments, except some few races. The behaviour of the various hybrids of flesh-coloured race was studied till F_2, and I think I am now able to make a certain conclusion about its genotypic constitution, but since my experimental results concerning this race are not yet complete, I will defer their publication to a future paper.

Flower-Colours.

The following colour-varieties were used in my experiments, viz. white, yellow, orange, flesh-coloured, red, and magenta (Pl. II). Besides, I could distinguish clearly two kinds of white, which are almost alike in external appearance, and yet genotypically different; they are called here *white-I* and *white-II* respectively (Pl. II, fig. 7–8).[1]

The colours of all parent varieties as well as their F_1-hybrids were recorded by means of " KLINCKSIECK et VALETTE, Code des Couleurs " (Paris, 1908); the results are indicated in the following Table :—

TABLE OF COLOURS.

Varieties and Crosses.	No. in the " Code."
Orange	176
Yellow	246
Flesh-colour	530
Red	6
Magenta	Between 551–556
Orange × white-I	191 or between 181–186
Orange × red	76
Magenta × white-I	566
Yellow × white-I	Between 166–171
White-II × orange	516
White-II × magenta	551
Orange × magenta	536

[1] I think that I have discovered still another race of white, which is externally quite similar to white-I, and yet genotypically different from it. I will call it *white-III*; its behaviour will be described below (p. 120).

Flower-colours on one and the same individual are often more or less different in early and late summer, and also at different hours of one day. Colours in the above Table are those recorded in July and generally soon after the opening of flowers.

Factors.

Before proceeding further I will mention the factors concerned in the colour production of varieties used by me. Of course the action of all these factors has been discovered only after many breeding experiments have been carried on, but in my description I will take the opposite course, because I will mention the action of the factors at first, and then go on to the crossing experiments.

The factors producing the flower-colours of *Portulaca* are as follows :—

1. *C*, fundamental factor for the production of any colour, *cc*-plant being *white* ; *C* alone, either in one or double dose, makes flower *orange* ;

2. *G* (*gilvus*), changes the orange colour produced by *C* into *yellow* ;

3. *R* changes the orange colour produced by *C* into *red* ;

4. *B* which I will call *blueing factor* changes the red colour produced by the co-operation of *C* and *R* into *magenta*. *B*, without *R*, even in presence of *C*, has no blueing action.

The factors specially concerned in the genotypic constitution of flesh-coloured and white-III races will not be considered in the present paper.

All my breeding experiments given below lead us to the conclusion that the varieties used by me may be expressed in respect to the colours of petals by the following genetical formulae, if we adopt the presence-and-absence hypothesis :—

1.	Orange	*CCggrrbb*	(Pl II, fig. 3).
2.	Yellow	*CCGGrrbb*	(„ „ „ 4).
3.	Red	*CCggRRbb*	(„ „ „ 2).
4.	Magenta	*CCggRRBB*	(„ „ „ 1).
5.	White-I	*ccggrrbb*	(„ „ „ 8).
6.	White-II	*ccggRRBB*	(„ „ „ 7).

In describing the cross experiments below the letters *gg* are omitted in genetical formulae, except in the Cross 11.

Crossing Experiments.

Cross I.   *White-I* × *orange* and *rice versa*. (Pl II, fig. 8 and 3).

$$cerrbb \times CCrrbb \qquad F_1 = Cerrbb$$

The white variety designated here by the name *white-I* has greenish stems and leaves, white petals, filaments, stigmas, and lightly greenish styles; while the orange variety has reddish stems and leaves, orange petals, red filaments, stigmas, and styles. The following crosses were made : orange × white-I in 1915, white-I × orange in 1916 and 1917. The F_1-plants have paler orange flowers than in the orange parent (s. the Table of Colours, p. 96). The offspring in F_2-and F_3-generation are indicated in the Table I ; it may here be remarked that the difference of homo-and heterozygous orange plants in these generations is so slight in respect to their colour that we could

TABLE I.

F_2-generation (1916, 1917, 1918).[1]

F_1-parent.	No. of F_2-offspring.		
	Orange	White.	Totals.
Orange × white-I.	42	11	56
White-I × orange, No. I.	17	7	24
„ „ „ II.	22	8	30
Total Actual	81	29	110
Expected	82·5 ± 1·5 †	27·5 ± 4·5	110

F_3-generation (1917, 1918).

Colour of F_2-parent.	No. of selfed plants.	No. of F_3-offspring.		
		Orange	White.	Totals.
Orange	4	131	0	131
		Expected 131	0	131
Orange	7	190	62	252
		Expected 189 ± 6·9	63 ± 6·9	252
White	4	0	28	28
		Expected 0	28	28

[1] The results of F_2-, F_3-generations, etc. in all my crosses were recorded in my field-book separately for each flower, but in the present paper the offspring derived from one cross are collected together for brevity's sake, except in some special cases.

† The figures affixed to the expected numbers denote always their respective standard errors calculated by the well-known formula $\sigma = \sqrt{npq}$.

hardly distinguish them exactly by their external appearance.

Thus we have in F_2 4 homo- and 7 heterozygous plants of orange colour, which accords, in spite of their small number, fairly well with the calculated numbers 3·7 and 7·3 respectively.

From all above described we see that the difference between orange and white-I varieties is due to one factor, and that this factor which we call C produces orange colour.

Though I have also raised the F_4 generation of the above cross it will not be perhaps worth while to describe here its details, and it may suffice simply to say that it has fully confirmed the results of the former generations.

During some generations of the above cross certain peculiar phenomena were often met with, which might somewhat confuse the Mendelian results obtained; thus, for instance, few *magenta* and *red* progeny are produced from seeds taken on orange or even white plants, and also few *orange* ones from those taken on white plants, etc. (naturally seeds being taken on selfed flowers). These phenomena will, according to my view, chiefly, though not all, belong to the so-called "reverse mutations," and since they were observed in many other cases they will be pointed out each time in the course of my description, and discussed together later in a separate chapter (s.p. 121 ff).

Cross II.   *Yellow × white-I.* (Pl II, fig. 4 and 8).
$CCGGrrbb × ccggrrbb$ $F_1 = CcGgrrbb.$

In order to study the genotypic constitution of the yellow variety I have done, firstly, its cross by the white-I (1915), and secondly, the two reciprocal crosses between it and the orange (1917). The F_1-hybrid produced by the latter crosses has borne flowers where yellow and orange patches of various size are irregularly scattered on each petal; in F_2 we were however impossible to exactly determine yellow and orange individuals, which we might have expected to have been produced by segregation, and the experiment was abandoned, at least for a time. As to the first of the crosses above cited, I was much more fortunate, though on account of the poor germination of seeds the behaviour of the F_2-generation could not be so fully investigated as might be wished for.

The F_1-hybrid made by crossing it by white-I has borne yellow flowers whose colour is nearly the same, or even more intense than in the yellow parent (s.

the Table of Colours, p. 96). The F_2-offspring were composed as follows :—

TABLE II.

F_2-generation (1916).

Yellow		Orange	White	Total.
Actual 71		23	37	131
Expected	$\begin{cases} 73.69 \pm 5.68 \\ 65.50 \pm 5.72 \end{cases}$	24.56 ± 4.47 32.75 ± 4.95	32.75 ± 4.95 32.75 ± 4.95	on $9:3:4$ basis on $2:1:1$ „

Thus the actual numbers of the three classes of the F_2-offspring agree with the expected ones, either on $9:3:4$ or on $2:1:1$ basis, though the agreement is much closer in the former than in the latter case. The final decision which alternative will be here realised, would however be possible only after the examination of the F_3-offspring; thus if the segregation under discussion will belong to the $2:1:1$ type all yellows should be heterozygous, and all oranges homozygous, whilst if it will belong to the $9:3:4$ type some yellows should be homozygous, and some oranges heterozygous. Unfortunately on account of the poor germination of seeds the F_3-generation contains very few individuals, and the results are consequently rather imperfect, because I was able to examine the F_3-offspring of only 2 oranges, 3 whites and 3 yellows in all of which generally very few seeds came to germination, viz. :—

    1 orange has thrown almost exclusively oranges (22 in all),[1]

    1 orange has segregated into 9 oranges and 2 whites,

    3 whites have thrown whites only (19 in all),

    1 yellow has thrown only 1 yellow,

    1 yellow has segregated into 5 yellows and 1 white,

    1 yellow has segregated into 6 oranges and 1 white.

The fact that the ratio of segregation in our case should be $9:3:4$ may be concluded from the presence of one heterozygous orange just cited, because in the $2:1:1$ type no orange should be heterozygous. This orange has undergone

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[1] Besides 22 oranges 1 magenta was found among the progeny. As discussed in Chapter "Mutations, etc.", I (p. 124 ff) this 1 magenta is regarded to have been produced by the reverse mutation, and consequently the orange parent is considered to be of the composition **CCggrrbb** (s. also Table VIII, No. 9; discussion, p. 125).

the segregation into 9 oranges and 2 whites, which agree fairly well with the calculated numbers, 8.25 ± 1.43 and 2.75 ± 1.43 respectively, and may be represented by **Ccggrrbb**, whilst another orange is homozygous and has the constitution **CCggrrbb**. As above stated, of three yellows of which I could have examined the offspring one has thrown only 1 yellow, and is quite useless for our experiment. The second has segregated into 6 oranges and 1 white, and since there will be no yellow which will show such segregation without throwing any yellow at all, it seems to me to be probable that the ratio is here really 9 yellows : 3 oranges : 4 whites, of which no yellow did germinate (i.e. **CcGgrrbb**). The third has produced 5 yellows and 1 white: it has segregated either in the ratio of 3 yellows and 1 white (i. e. **CcGGrrbb**), or in that of 9 yellows, 3 oranges, and 4 whites like the second, of which no orange did germinate. No homozygous yellow (**CCGGrrbb**) came under my observation, and this is not to be astonished, because we should have only 1 such out of 9 yellows. Our conclusion is therefore that we have in our case in F_2 the $9 : 3 : 4$ type of segregation, that the yellow variety has in respect to its flower-colour one more factor than the orange, and that consequently the cross between yellow and white-I varieties is based on the two factors difference, viz. **C** and **G**.

Cross III.   *Red × orange* and *vice versa* (Pl II, fig. 2 and 3).
CCRRbb × CCrrbb $F_1 =$ **CCRrbb**

The F_1-hybrid has red flowers whose colour intensity is almost similar to that of the red parent (s. the Table of Colours, p. 96). The F_2-and F_3-offspring are composed as in Table III (s. p. 102):—

As will be seen from this Table, though 6 out of 8 oranges have given rise in F_3 exclusively to oranges ($=70$), one of the remaining two has thrown 3 oranges and 1 red, and another 5 oranges and 20 reds. Despite all such facts these two orange parents (i. e. F_2 plants) are considered to be homozygous like all others, so that all 8 oranges in F_2 are to be expressed by the formula **CCrrbb** (s. Table VIII, Nos. 19 and 11, and also discussions about them in Chapter " Mutations, etc.," IV and II respectively, p. 128 and p. 127).

As regards 11 reds in F_2 whose behaviour in F_3 I could have examined 6 were proven to be homo-, and 5 to be heterozygous (expected, 3.65

TABLE III.

F_2-generation (1917).[1]

F_1-parent.	No. of F_2-offspring.		
	Red	Orange	Totals
Red × orange	21	6	27
Orange × red	27	11	38
Totals	48	17	65
Expected	48·75±3·5	16·25±3·5	65

F_3-generation (1918).

Colour of F_2-parent	No. of selfed plants		No. of F_3-offspring.		
			Red	Orange	Totals.
Red	6		35	0	35
		Expected	35		35
Red	5		85	23	108
		Expected	81±4·5	27±4·5	108
Orange	6		0	70	70
		Expected	0	70	70
*Orange+	1		1	3	4
		Expected	0	4	4
*Orange	1		20	5	25
		Expected	18·75±2·2	6·25±2·2	25

homo: 7·30 hetero) (s. Table III), so that the ratio of individuals in these two classes of reds does not well agree with what we might expect theoretically, but much importance should not be laid on this fact in view of the small number of individuals.

From the above experiments we see that the difference between orange and red is due to one factor which we call R and which changes the orange caused by C into red.

[1] Though, as may be seen from the results in F_3-generation, there are two kinds of reds (homo- and heterozygous), they are collected in F_2 under the class red, because they are not exactly distinguishable from each other by their external appearance.

+ The parent prefixed with an * denotes one which has produced some unexpected individuals among its offspring. Thus, for instance, in this No. we find besides 3 oranges 1 red which was quite unexpected. For the discussion of these phenomena s. pp. 124.

Cross IV.   *White-I × white-II* and *vice versa*, etc. (Pl. II, fig. 8 and 7).
$$cerrbb × ccRRBB \qquad F_1 = ccRrBb.$$

At the beginning of my breeding experiments I have conducted the crosses between the various white varieties, because it was thought not to be impossible that the cross of two certain whites might produce the progeny with coloured flowers, as in the classical example of Sweet Pea. For instance, the cross between white-I and white-II and its reciprocal have been done in 1915; all F_1-offspring were found to bear white flowers in both cases, and it was the same in F_2-progeny. The crosses between all white varieties, including white-III also, made in various ways agree in the fact that they never give rise to coloured plants, both in F_1 as well as F_2, and evidently in any further generation. The treatment of flowers of all these varieties by ammonia vapour according to Miss WHELDALE[1] and SHIBATA[2] does not give yellow reaction, indicating that they do not contain flavones. All white plants are *cc*, because the presence of *C* produces the orange colour, as above stated.

Cross V.   *White-I × magenta* and *vice versa*. (Pl II, fig. 8 and 1).
$$cerrbb × CCRRBB \qquad F_1 = CcRrBb$$

The cross, white-I × magenta and its reciprocal were made in 1916 and 1917 respectively. In both F_1-hybrids we see that magenta is almost perfectly dominant to white (s. the Table of Colours, p. 96). On account of very poor germination of seeds the number of individuals is rather small, especially in F_2, but the actual results agree fairly well with the theoretical expectation. The Table IV indicates the results of the F_2- and F_3-generation. (s. p. 104).

We have thus in F_2 homozygous magentas (***CCRRBB***): magentas segregating into 3 magentas and 1 orange (***CCRrBb***): magentas segregating into 3 magentas and 1 white (***CcRRBB***): magentas segregating into 9 magentas, 3 oranges, and 4 whites (***CcRrBb***) in the ratio $1:1:1:4$, their expected numbers being $0.8:1.6:1.6:3.1$ respectively. Furthermore, we have 5 homo- and 6 heterozygous oranges, while their theoretical numbers are 3.65 and 7.30 respectively. Of 7 whites 5 have produced only whites.

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[1] *Journ. of Genetics*, Vol. 4, 1915, p. 113.

[2] *Bot. Mag.*, Tôkyô, Vol. 29, 1915, pp. 121-122.

Of the remaining 2 one has produced 1 orange besides 13 whites, and another nothing but 1 orange : as discussed in Chapter ' Mutations, etc.", I, I consider both, in spite of such facts, to be the whites of the constitution *ccrrbb* (s. Table VIII, Nos. 12 and 13 : and discussions about them, p. 124), so that all 7 white parents here are regarded to be genotypically equivalent, viz. *ccrrbb*.

TABLE IV.

F_2-generation (1916, 1917).

F_1-parent	Magenta	Orange	White.	Totals
Magenta × white-I	126	51	55	232
White-I × magenta	16	2	10	28
Totals	112	53	65	260
Expected	116·25±7·00	18·75±6·29	65±6·98	260

F_3-generation from white-I × magenta (1917).

Colour of F_2-parent	No. of selfed plants		No. of F_3-offspring			
			Magenta	Orange	White	Totals
Magenta*	1		2	0	0	2
		Expected	2	0	0	2
Magenta	1		3	0	1	4
		Expected	3	0	1	4
Magenta	1		5	4	0	9
		Expected	6·75±1·3	2·25±1·3	—	9
Magenta	t		84	27	28	139
		Expected	78·19±5·8	26·06±1·6	34·75±5·1	139
Orange	5		0	18	0	18
		Expected	0	18	0	18
Orange	6		101	24		125
		Expected	3	93·75±1·8	31·25±1·8	125
White	5		0	0	78	78
		Expected	0	0	78	78
*White	1		0	1	13	14
		Expected	0	0	14	14
*White	1		0	1	0	1
		Expected	0	0	1	0

† The number of segregates from this magenta parent is so small that it is considered to be homozygous only provisionally.

From Table IV as well as what I have just stated we will see that we have here apparently to deal with a typical case of dihybrid segregation.

In the various cases studied till now by several authors it was found that for the production of bluish-red colour (magenta, purple, etc.) the factor for producing the red anthocyanin and that for changing the latter into bluish-red one participate; thus, for instance, in flowers of *Lathyrus odoratus* (**R** and **B**, BATESON), and of *Antirrhinum majus* (**F, R, D,** BAUR;[2] **R** or **L, T** and **B,** Miss WHELDALE)[3] in the aleurone of Maize (**R** and **P,** EAST and HAYES;[4] **R** and **Pr,** EMERSON)[5] etc. The question naturally arises whether the magenta colour of flowers of *Portulaca* is not also due to the combined action of such factors. The results of our present cross do furnish, as will be seen from what was stated above, no positive evidence towards such a conclusion, but some other breeding experiments, especially the Cross VIII (p. 112), prove beyond all doubts that the magenta colour in our case is due, quite similarly as in all cases above cited, to the action of the two factors which I call **R** (reddening) and **B** (blueing) respectively. We have therefore in the hybrid white-1 × magenta or its reciprocal a trihybrid instead of a dihybrid, inasmuch as it may be expressed by the genetical formula **CcRrBb**, as above given. If the three factors **C, R, B** contained in this hybrid will make free assortment, we should have eight kinds of male and female gametes, i.e. **CRB, cRB, CrB, crB, CRb, cRb, Crb, crb,** and consequently the ratio of 27 magentas : 9 reds : 12 oranges : 16 whites in F_2.[6] The reason why notwithstanding this we have in our case the ratio of 9 magentas : 3 oranges : 4 whites in F_2 will be seen, when we think that of the three factors **C, R, B** contained in magenta the two latter are in the state of complete "coupling" or "linkage" (to use the word more frequently adopted recently), and act just like one single factor, so that we have here simply four kinds of male and female gametes, i.e. **CRB, cRB, Crb, crb.** If **R**

[1] MENDEL's *Principles of Heredity,* p. 91.

[2] *Zeitsch. f. ind. Abstamm. u. Vererbungslehre,* Bd. 3, 1910, pp. 41–43.

[3] Ibid., p. 326; also *Journ. of Genetics,* Vol. 4, 1915, p. 110.

[4] *Conn. Agric. Exp. Stat., Bull.* No. 167, 1911.

[5] *Cornell Univ. Agric. Exp. Stat.,Memoirs* 16, 1918.

[6] This is somewhat similar to the F_2-generation of the classical example of Sweet Pea (s. BATESON, l. c., p. 91), though we have in the latter 28 whites instead of 12 oranges and 16 whites, since the factor *C* does not produce any colour in Sweet Pea.

and *B* were always absolutely linked to each other, we will have naturally no means of discerning the composite nature of this factor-complex, but sometimes the linkage is broken down, at least partially, and we are then enabled to disclose its real nature (s. the Cross VIII, p. 112 ff.)

<div align="center">

Cross VI.   *White-II × magenta*. (Pl. II. fig. 7 and 1).

ccRRBB × **CCRRBB** $F_1 = CcRRBB$.

</div>

Though white-II is externally very similar to white-I, it may differ sometimes from the latter in certain respects. The white-II bears white petals like the white-I; but sometimes (not always) they have few magenta stripes or spots; filaments are white, but often some few ones are magenta (s. p. 120). The F_1-hybrids (1918) bear magenta flowers, whose colour intensity is almost perfectly similar to that of the magenta parent (s. the Table of Colours, p. 96). As the white-I and white-II are genotypically different from each other, the composition of the F_2-offspring produced ex white-II × magenta is quite different from that of those ex white-I × magenta (Cross V). Thus we have the results shown in the Table V (s. p. 107.)

In this Table we see both in F_2 and F_3 the production of a certain number of unexpected individuals. Thus 8 out of 10 F_1-plants have segregated in F_2 into magentas and whites, as was just expected, whereas each of the remaining two has produced besides these two classes of the segregates 1 orange which is quite unexpected. The formation of these two oranges is very difficult to be accounted for, and it might be due to the contamination from other families, though utmost care was taken for avoiding such. Till the contrary to the latter assumption will be definitely established these two oranges will not be taken into account, and then we see clearly that each of these F_1 parents is of the constitution **CcRRBB**.

In F_3 generation three magentas have produced among others 1 flesh-coloured, 1 orange and 1 pseudo-white (Table V, F_3, Nos. 2, 3, 4), and two other magentas 3 flesh-coloured and 5 red plants (Table V, F_3, Nos. 6 and 7). Since the genotypic constitution of flesh-coloured and pseudo-white races is not yet exactly known it is naturally impossible to make any surmise about the mode of their production (though probably by mutation), and these unexpected plants must here be left out of account. The production of the orange and

TABLE V.

F_2-generation (1919)

F_1-parent	No. of plants selfed	No. of F_2-offspring			
		Magenta	White	Orange	Totals
White-H × magenta	8	509	163	0	672
„ „ „	1	107	48	1	156
„ „ „	1	10	2	1	13
Totals	10	626	213	2	841
Expected		630·75±12·6	210·75±12·6	0	841

F_3-generation (1920).

Colour of F_2 parent	No. of plants selfed.	No. of F_3-offspring						
		Magenta	White	Red	Flesh	Orange	Pseudo-white[1]	Totals
Magenta, No. 1	3	113	42	—	—	—	—	155
„ „ 2	1	28	13	—	—	1	—	42
„ „ 3	1	40	23	—	1	—	—	64
„ „ 4	1	16	3	—	—	—	1	26
Totals	6	203	81	—	1	1	1	287
Expected		215·25±7·3	71·75±7·3		0	0	0	287
Magenta, No. 5	2	36	—	—	—	—	—	36
„ „ 6	1	35	—	—	1	1	—	37
„ „ 7	1	12	—	5	2	—	—	19
Totals	4	83	—	5	3	1	—	92
Expected		92	—	0	0	0	—	92
White, No. 1	4	—	72	—	—	—	—	72
„ „ 2	1	2	42	—	—	—	—	44
„ „ 3	1	5	77	—	—	—	—	82
Totals	6	7	181	—	—	—	—	188
Expected		0	188	—	—	—	—	188

the red in this case might be due to the so-called "loss-mutation," (s.p.127). If what is above stated will be taken into consideration we have clearly to think the first three magenta parents to be of the composition $CcRRBB$,

For pseudo-white s. p. 119.

and the remaining two of that **CCRRBB**. Of 6 whites 2 (Table V, F₃, Nos. 2 and 3) have produced besides white offspring 7 magenta ones. That each of these two white parents is to be regarded to have the constitution **ccRRBB** will be discussed later in this paper (s. Table VIII, Nos. 21 and 22, discussions in "Mutations, etc." I).

From the results in F_1 above indicated we see that we have in F_2 4 homo- and 6 heterozygous magentas (expected, 3:3 and 6:6), and that all whites are homozygous, whence we may conclude that the actual and the expected results agree fairly well to each other. Hence it is evident that this cross is based upon one single factor difference. We can also easily understand the reason why this cross will produce quite different results from those in the Cross V where white-I is used instead of white-II, because the latter contains both **R** and **B** like our magenta variety, while white-I has none.

Cross VII.   *White-II × orange* and *vice versa*. (Pl. II, fig. 7 and 3),
$$ccRRBB × CCrrbb \qquad F_1 = CcRrBb$$

The cross between white-I and orange has been described before (s. p. 98 ff). That white-II is genotypically different from white-I in spite of their external resemblance is especially clear, when we make the cross between the former and the orange, because we get then quite different results : the F_1-hybrids, whether from white-II × orange or its reciprocal, bear always magenta flowers, whose colour intensity is almost equal to that in our magenta variety (s. the Table of Colours, p. 96). As indeed white-II (**ccRRBB**) may be considered to be a magenta variety which remains colourless on account of the absence of **C**, it is quite natural that its mating with the orange will produce the magenta, **C** being introduced from the latter parent. The genotypic constitution of the F_1-hybrid in the present case is therefore perfectly equal to that in the Cross VI (p. 106), so that the composition of the F_2- and F_3-offspring should be naturally quite the same as in those derived from the same cross. This fact could be perfectly confirmed experimentally, as we will see from the F_2 and F_3 offspring presented in the Table VI, A and B.

TABLE VI. A.

F₂-generation (1916, 1917, 1920).

F₁-parent.	No. of the F₂-offspring				Totals
	Magenta	Orange	White	Red	
White-II × orange, No. 1	35	13	17		65
„ „ „ „ 2	81	29	34	14	136
Orange × white-II	96	54	43		189
Totals	212	83	94	1	390
Expected {	219.37±9.8	73.12±7.7	97.5 ±8.6	0	390††
	195.00±9.9	97.50±8.6	97.50±8.6	0	390†††

As we see from the above Table, the actual results in F₂ agree with the theoretical, either on 2 : 1 : 1 or 9 : 3 : 4 ratio, just as in the Cross II, though somewhat better on the latter basis, and the question which possibility will here occur in reality was decided by raising the F₃-generation ex white-II × orange, No. 1 and orange × white-II cited in the Table VI, A. The results of this cultivation are shown in Table VI B (s. p. 110):—

As we see in this Table magenta No. 2 has produced 75 magentas and 42 reds, and yet it is to be regarded as having the constitution **CCRRBB** (s. Table VIII, No. 23; discussion in Chapter " Mutations, etc.," III, p. 127)' In respect to the fact that magenta No. 6 should be considered to be **CcRrBb** s. Table VIII, No. 24, and discussion, p. 129. — The orange No. 2 is considered to be **CCrrbb,** and the orange Nos. 4 and 5 to be **Ccrrbb** (s. Table VIII, Nos. 25, 26, and 27; discussions, in " Mutations, etc." I).— White No. 2 composed of 4 plants has produced together besides whites some magentas and reds; each of these 4 is despite this fact regarded to be **ccrrbb** (Table VIII, No. 28; discussion in Chapter " Mutations, etc.," III). From the Table VI as well as from what was just stated the following conclusion may be drawn:—we have in F₂ homozygous magentas (**CCRRBB**): those segregating into 3 magentas and 1 orange (**CCRrBb**): those segregating into 3 magentas and 1 white (**CcRRBB**): those segregating into 9 magentas, 3 oranges, and 4 whites (**CcRrBb**), in the ratio 3 : 9 : 7 : 7,

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† This 1 red is not taken here into consideration; s. the foot note p. 110.
†† On 9:3:1 basis.
††† On 2:1:1 basis.

TABLE VI, B.

F_3-generation (1917, 1918).

Colour of F_2-parent	No. of selfed plants		Magenta	Red	Orange	White	Totals
					No. of F_3-offspring		
Magenta, No 1	2		36	-----	-----	-----	36
		Expected	36		-	-----	36
* ,, ,, 2 ...	1		75	42	-----	-----	117
		Expected	117	0	-----	-----	117
,, ,, 3	9		109	-----	37	,-----	146
		Expected	109·5±5·3	-----	36·5±5·3	,-----	146
,, ,, 4	7		61	-----	-----	26	87
		Expected	65·25±4·04	-----	----	21·75±4·04	87
,, ,, 5	6		40	-----	21	24	85
		Expected	47·8±4·8	-----	15·9±3·6	21·2±4·0	85
,, ,, 6ª ...	1		28	2	3	11	44
		Expected	s p. 129	-----		-- ---	-----
Orange, ,, 1	7		-----		108	-----	108
		Expected	-		108	,-----	108
* ,, ,, 2 ..	1		- ---	1	1	-----	2
		Expected	----	0	2	-- ---	2
,, ,, 3	9		-----	-----	190	73	263
		Expected	-----	-----	197·25±7	65·75±7	263
* ,, ,, 4	1		12	2	45	30	89
		Expected	0	0	66·75±4·1	22·25±4·1	89
* ,, ,, 5 ...	1		4	-----	1	2	7
		Expected	4	-----	5·25±4·1	1·75±4·1	7
White ,, 1	18		-----	-----	-----	215	215
		Expected	-----	-----	-----	215	215
* ,, ,, 2	4		7	-----	5	42	54
		Expected	0	-----	0	54	54

theoretically $2·9 : 5·8 : 5·8 : 11·6$ respectively. Furthermore, we have 8 homo- (*CCrrbb*) and 11 heterozygous oranges (*Ccrrbb*), theoretically 6·3 and 12·6 respectively. Besides, all whites are considered to be homozygous, as above

* That the appearance of 2 reds in the offspring of this No. which is considered to be of the genotypic constitution *CcRrBb* is due to the formation of a certain number of the gametes *CrB, CRb, crB, cRb*, i.e. to the change of the complete " coupling " between *R* and *B* into a partial, will be discussed p. 129. The appearance of 1 red in F_2 (s. Table VI, A, white-4 × orange, No. 2) may also be due to the same cause.

stated. We have therefore proven that we have in F_2 the ratio 9 magentas : 3 oranges : 4 whites, and we see that in this generation we have the complete linkage of R and B just as in Cross V.

That the F_1-hybrid under discussion produces the gametes CRB, cRB, Crb, crb, but not CrB, crB, CRb, CRb (except very rare cases, s. Table VI, B), will be seen also by crossing it back by white-I ($ccrrbb$), i. e. that variety which contains neither C nor R nor B, thus, for instance, this crossing was done in 1919, and we had in 1920:—

	Magenta	Orange	White	Total
White-I × orange) × white-I	27	21	36	84
Expected	21 ± 1.0	21 ± 1.0	42 ± 1.6	84

This cross indicates us clearly what kinds of gametes are produced by the F_1-hybrid, and from the results we see that B and R are completely linked to each other, because if the free assortment were the case, we should have the ratio 1 magenta : 1 red : 2 oranges : 4 whites instead of that 1 magenta : 1 orange ; 2 whites, as it was actually the case.

The experiment of Miss YASUI on the crossing of white and pale yellow, giving rise to magenta F_1-plants,[1] seems to agree with my present cross in several respects, though she has used pale yellow instead of orange. Though her experiment ends with F_3, the actual numbers of magentas, yellows and whites in the latter generation accords pretty well with the expected, and there will be perhaps no doubt that she had to deal in this generation with the 9 : 3 : 4 segregation. Her explanation in respect to the appearance of magentas in F_1 agrees also with what I have above stated about the same phenomenon ; the difference between her view and mine lies however in the fact that while she considers the magenta colour to be due to one single factor R (in co-operation with C), I regard the same colour to be due to the factor-complex RB (naturally in co-operation with C). Though from the analogy with several cases studied till now by many authors the combined action of some such factors for the production of the magenta colour seemed to me a

[1] *Bot. Mag.*, Tôkyô. Vol. 34, 1920, pp. 59-63.

priori very probable, I could find no such indication at the beginning of my experiment. On studying, however, the F_2-generation of the present cross, I have found some reds in the offspring of one magenta F_2-parent (Table VI, B: Magenta, No. 6). This points out naturally towards the composite nature of the magenta factor, and I was able to establish the fact by the Cross-experiment VIII.

Cross VIII. *Magenta × orange*. (Pl. II, fig. 1 and 3).

$$CCRRBB × CCrrbb \qquad F_1 = CCRrBb.$$

The F_1-hybrid bears magenta flowers (s. the Table of Colours, p. 96). The F_2-offspring are composed as in the following Table :—

TABLE VII, A.

F_2-generation (1917).

No. of F_1-plants selfed	No. of F_2-offspring		
	Magenta	Orange	Total
29	151	73	224
Expected	168 ± 6·5	56 ± 6·5	224

The deviation of the actual results from the theoretical calculated on the 3 : 1 basis is 17, and consequently 2·6 times the standard error (= 6·5). Thus the actual results are not in very good agreement with the expected; the chief cause of this discrepancy is in all probability to be sought in the poor germination of seeds, and I think that we have here in spite of discrepancy a case of segregation into 3 magentas and 1 orange.[1] The lack of reds in this case is evidently due to the absolute linkage of **R** and **B**, as it was the case in the Cross V, VI and VII, or at least to the linkage of very high intensity where so few reds are expected that they will not appear at all unless an enormous number of plants are in cultivation.

Now what is very remarkable about the F_3-offspring derived from the F_2-plants under discussion is the fact that some of the magentas have under-

[1] We may have 4 such case out of about 112 trials as the result of random sampling

gone the segregation into *magentas, reds* and *oranges* instead of that into magentas and oranges simply, as will be seen from the following Table:

TABLE VII, B.

In this Table the offspring derived from each magenta individual are exceptionally recorded separately.

F_3-generation plots

Colour of F_2-parent	No. of selfed plants	No. of F_3-offspring			
		Magenta	Red	Orange	Totals
Magenta, No. 1	1	14†			1
" " 2	1	6			6
" " 3	1	16			16
" " 4	1	33			33
Totals	3	55			55
Expected		55			55
" " 5	1	7		1	8
" " 6	1	6		1	7
" " 7	1	14		1	15
" " 8	1	3		2	5
" " 9	1	3		1	4
" " 10	1	10		4	14
" " 11	1	15		2	17
" " 12	1	4		1	5
Totals	8	58		16	74
Expected		55.5±3.7		18.5±3.7	74
" " 13	1	54	5	16	75
" " 14	1	6	2	3	11
" " 15	1	3	1	1	5
" " 16	1	7	2	.	9
" " 17	1	.	1	1	2
" " 18	1	12	2	6	20
" " 19	1	18	3	6	27
" " 20	1	17	1	9	27
" " 21	1	12	1	4	17
" " 22	1	20	1	10	31
" " 23	1	32	1	8	41
Totals	11	181	20	64	265
Expected	s. below(p.111)				
Orange	12			201	201
Expected				201	201

† This is not entered in the total.

From the results given in the Table VII, A we expect to have 1 *CCRRBB*, 2 *CCRrBb* and 1 *CCrrbb* in the F_2-generation.   In the Table VII, B showing the F_3-offspring we have the F_2-parents of magenta colour, No. 1–23. Of these No. 1 has produced only 1 magenta plant and is not entered in the total, because it indicates naturally nothing for our experiment. Nos. 2–4 belong to *CCRRBB*, and Nos. 5–23 to *CCRrBb* whilst each of 12 oranges belongs to *CCrrbb*, because it has produced, nothing but oranges.   We have thus 3 *CCRRBB* : 19 *CCRrBb* : 12 *CCrrbb*, theoretically $8·5 : 17·0 : 8·5$. Of the heterozygous magentas *CCRrBb* (i. e. Nos. 5–23) each of Nos. 5–12 has segregated into magentas and oranges, just as did the F_1-hybrid in F_2, their approximate ratio being $3 : 1$ in total, and evidently this is so, because in these magentas the factors *R* and *B* remain in absolute linkage.   On the contrary, in each of magentas, Nos. 13–23, we observe the appearance of the *reds*, and this is clearly due to the breaking down of the complete linkage between these factors. Since we have in all 181 magentas, 20 reds and 64 oranges, i.e. $7·6\%$ reds, there are too few reds to consider that the free assortment has taken place between *R* and *B*, because we should have in the latter case nearly 149 magentas, 50 reds and 66 oranges $(9 : 3 : 4)$, i.e. $18·9\%$ reds.   It is quite evident that in our present case the linkage has been *changed from complete to partial*, or at least has changed its intensity from very high to low.   What is then the ratio of " coupling " or " linkage " in the latter case?   For its determination the following calculations were made :—

	Magenta	Red	Orange	Totals	
	(CRB)	(CRb)	($CrB + Crb$)		
Actual	181	20	64	265	
Expected	$178·5 \pm 7·6$	$20·2 \pm 1·5$	$66·2 \pm 7·1$	265	on $5 : 1 : 1 : 5$ basis
	$181·2 \pm 7·6$	$17·6 \pm 1·2$	$66·2 \pm 7·0$	265	„ $6 : 1 : 1 : 6$ „

If we calculate the closeness of fit by the method of PEARSON we find for the first and the second case $\chi^2 = 0·1099$ and $0·4006$ respectively, each of which should indicate an almost perfect agreement of the actual number with the

theoretical. So it is clear that we have here to deal with a case of linkage belonging to either one of the two above series or at least to some series similar to it.

To sum up: the cross magenta × orange has segregated in F_2 in the ratio of 3 magentas and 1 orange, because R and B are completely linked together; in F_3 the linkage became partial in some magentas, and consequently their F_4-offspring contain *reds* besides magentas and oranges.

If we will adopt the chromosome theory of MORGAN we have, for instance, the gametes CRB, CRb, CrB, Crb in the ratio $5.5 : 1 : 1 : 5.5$ (5.5 being the average of 5 and 6 in the two series of linkage above cited), and consequently 15.4% cross-overs and 84.6% non-cross-overs respectively.[2] The following consideration may then be made. The factors R and B are located very near in the same chromosome, and consequently closely linked together as the rule. But sometimes the crossing-over takes place, so that they come to lie in two different, though homologous, chromosomes, the ratio of cross-overs against non-cross-overs being found to be $15.4 : 84.6$.

The facts which point out towards the variation of the linkage ratio of certain factors have been sometimes observed till now. To cite some instances, GREGORY in his researches on *Primula sinensis*, has found in the F_2-offspring ex $Ms \times mS$ (magenta and long-styled by red and short-styled) the complete linkage between M and S, whereas in those ex $MS \times ms$ (magenta and short by red and long) the partial one belonging to the series $7 : 1 : 1 : 7$ has been observed between the same factors.[3] BAUR, in his experiments in *Antirrhinum majus*, has found in the F_2-offspring ex $FFGG \times ffgg$ (red and *picturatum* flower by non-red and *non-picturatum*) that the linkage ratio between F (red) and G (*picturatum*) is variable in different cases ($3 : 1 : 1 : 3$, $4 : 1 : 1 : 4$, $7 : 1 : 1 : 7$, or even $1 : 1 : 1 : 1$, i.e. normal).[4] In *Lathyrus odoratus* BATESON

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[1] S. PEARSON, *Tables for Statisticians and Biometricians*, Cambridge, 1914, Table XII.

[2] If we calculate the linkage ratio according to the formulæ of EMERSON (Amer. Naturalist, Vol. 50, 1916, pp. 1411–1420) we have from the corrected phænotypic ratios CRB : CRb : CrB : $Crb = 178.75 : 20 : 20 : 46.25$ (from the actual $181 : 20 : 20 : 64-20 = 181 : 20 : 20 : 44$) $r = 6.89$ and $s = 1.34$ and consequently the linkage ratio $= r + s = 5.0 : 1$.

[3] *Journ. of Genetics*, Vol. 1, 1911, p. 129.

[4] *Zeitsch. f. ind. Abstamm. u. Vererbungslehre*, Bd. 6, 1912, p. 294 ff; and *Einleitung in die*

and PUNNETT have found in F_2 ex **BL** . **bl** (purple flower and long pollen by red and round) the linkage of the series $7 : 1 : 1 : 7$ between **B** and **L**, whilst in further generations of the same cross that of the series $15 : 1 : 1 : 15$ has been observed;[1] also in the same plant and in the same kind of the cross PUNNETT has observed sometimes the $7 : 1 : 1 : 7$ linkage, and sometimes the $10 : 1 : 1 : 10$ one.[2] Again, in the progeny of one of his Maize hybrids (endosperm horny-waxy, coloured-white) KEMPTON has generally detected the linkage belonging to the series $3 : 1 : 1 : 3$, whilst in the progeny derived from the same parents he could find that of the series $3 : 2 : 2 : 3$, though exceptionally.[3] Recently experiments to modify artificially the amount of linkage in *Drosophila* by the influence of varying temperatures have been carried on with success by PLOUGH.[4] The variation of the linkage ratio in the cross under discussion is thus no unprecedented fact : whether it is due to a certain change in the internal mechanism, or to the influence of the environment, or to certain other reasons is however yet unsettled, and will be the interesting subject of future studies. Furthermore, though in our present case we have seen the complete linkage of **R** and **B** in F_2 and its change into a partial in F_3, it is very doubtful whether such would be always the case. It seems to me very probable that there might be several modifications. Thus, for instance, the absolute linkage of **R** and **B** seen in F_2 might remain as such in F_3 ; on the contrary, their partial linkage or even their free combination might occur already in F_2, etc., etc. Still further, some other important questions will await the answer. Thus the fact should be determined whether the ratio of linkage will remain constant in all cases. Also it will be necessary to investigate the fact whether or not this ratio will be equal on the male as well as the female side of one and the same plant. As one of the extreme cases of the inequality of the linkage ratio on the two sides we might have, for instance, that where the linkage is complete on one side and partial on the other; nor would it be not impossible that on the one side we

experimentelle Vererbungslehre, 3. u. 4. Aufl., 1919, p. 172 ff

[1] *Report to the Evolution Committee R. S.*, Report 4, 1909, p. 11 ff.

[2] *Journ. of Genetics*, Vol. 3, 1913, pp. 78–79 ; also ibid., Vol. 6, 1917, p. 187.

[3] *U. S. Department of Agric., Bull.* 754, 1919, p. 78 ff.

[4] *Journ. of experimental Zool.*, Vol. 24, 1917, pp. 147–209.

see some form of linkage, and on the other the free assortment of the gametes. Experiments for determining all such important points were already begun.

Some further breeding has been performed in respect to the present cross, but I will here simply state shortly what I have found about the reds in F. Of 20 reds in all which have appeared in F, only two could be selfed, and their offspring (F) were examined; the results were as follows:

	Magenta	Red	Orange	Totals
No. 1	1*	32	9	42
„ 2	——	24	14	38
Totals	1	56	23	80
Expected		60±3·8	20±3·8	80

Hence we see that both reds examined are heterozygous in respect to R, i.e. $CCRrbb$. When R and B are linked in the ratio $5:1:1:5$ or $6:1:1:6$ we should have $CCRrbb : CCRRbb$ in the ratio $10:1$ or $12:1$ respectively, and thus there is no wonder that we have met with no homozygous reds at all, because only two reds were examined.

Multiple Allelomorphism.

One of my objects of investigation of the flower-colours of *Portulaca* was to pursue, if we have there a case of the so-called "multiple allelomorphism" of Morgan and his school: thus white, orange, flesh-colour, yellow, red and magenta in our varieties might be a series of multiple allelomorphs which occupy the corresponding loci in certain homologous chromosomes. We have however above seen that the results of all crosses in *Portulaca* executed by me are very well explainable by means of usual unit factors. The following remarks might also be of some interest. If my experiments in *Portulaca* had ended with the F_2-generation, we might perhaps be led in certain cases at least to conclude that we have then to deal with a case of multiple allelomorphism. For instance, I have found that the F_2-offspring ex red ×

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† This magenta came to development, because at least one gamete CRB was produced by reversion. Similar facts were observed in respect to No. 24 (Table VIII), F_4-generation (discussion, p. 129) and No. 29 (same Table, discussion p. 127).

magenta contain 126 magentas and 30 reds, theoretically 117 ± 5.4 and 39 ± 5.4 respectively on $3:1$ basis; further, we have seen that the F_2-generation ex red × orange (or orange × red) (p. 101) as well as that ex magenta × orange (p. 112) segregate each into $3:1$ respectively, i.e.

1.   ***CCRRbb*** × ***CCrrbb***

     (red)   ×   (orange)

2.   ***CCRRBB*** × ***CCRRbb***

     (magenta)   ×   (red)

3.   ***CCRRBB*** × ***CCrrbb*** :

     (magenta)   ×   (orange)

consequently we should have in (3) the segregation $9:3:4$ instead of $3:1$, were it not for the complete linkage between ***R*** and ***B***, as was stated before (p. 114 ff.) Our present case is very similar to that of *Aquilegia* leaves, green, *chlorina* and *variegata*, the well-known so-called "Dreieck" of BAUR[1] or to that of the Rabbit, self-coloured, Himalayan and albino studied by PUNNETT.[2] Thus, for instance, we have in *Aquilegia*

1.   ***aaBB*** × ***aabb***

     (green)   × (*chlorina*)

2.   ***AAbb*** × ***aabb***

     (*variegata*) × (*chlorina*)

3.   ***aaBB*** × ***AAbb***

     (green) × (*variegata*)

and in the Rabbit

1.   ***CCSS***   ×   ***CCss***

     (self-coloured) × (Himalayan)

2.   ***CCss***   ×   ***ccss***

     (Himalayan) × (albino)

3.   ***CCSS***   ×   ***ccss***

     (self-coloured) × (albino)

[1]   *Zeitsch. f. ind. Abstamm. u. Vererbungslehre*, Bd. 6, 1912, pp. 215–216.

[2]   *Journ. of Genetics*, Vol. 2, 1912, pp. 236–237 ; also ibid., Vol. 5, 1915, pp. 45–46.

In each of these crosses their F_1-offspring are composed approximately of 3 dominants and 1 recessive, and the fact that in each of the above (3) we have a monohybrid instead of a dihybrid segregation is explained by the assumption that in *Aquilegia* **A** and **B**, and in the Rabbit **C** and **S** are in absolute linkage. This explanation, though yet hypothetical, seems to me not improbable in view of my results in the cross magenta × orange just mentioned, because in the latter case the absolute linkage exactly similar to that assumed in *Aquilegia* and the Rabbit has been, not merely assumed, but adequately proven.

MORGAN and his school are inclined to explain the case of *Aquilegia* and the Rabbit above given by means of their theory of multiple allelomorphism.[1] I will not enter here into the discussion which of the two alternative hypotheses will better explain the above cases, but I will simply state that what I have observed in respect to the cross in *Portulaca* corresponds exactly to what the hypothesis advanced by BAUR and PUNNETT demands.

Note on the so-called "pseudo-white" Race.

Pseudo-white is the name given to a peculiar race of white colour which has newly arisen in my culture. In this race leaves and stems are reddish as in coloured varieties, but the corolla is white, though slightly flashed with magenta, especially in its periphery, and each petal is generally furnished with a magenta spot at its basal part ("Herzfleck" of German authors); filaments, styles and stigmas are reddish (Pl. II, fig. 6). This race may belong either to that type in which the production of anthocyanin is inhibited, or to that which Miss WHELDALE calls "partial albino."[2] One pseudo-white was produced in the F_1-offspring ex white-II × magenta (s. the Table V), in all probability by mutation, but it may be produced regularly in the offspring of certain crosses of white-III, and very probably according to Mendelian rule: thus, for instance, the cross orange × white-III has been followed up till F_4, and this fact has been made probable, though the details of the results obtained by me will not now be published, because they are yet far from complete. Below I

[1] *The Mechanism of Mendelian Heredity.* New-York, 1915. pp. 157; also, STURTEVANT, *Amer. Naturalist*, Vol. 47, 1913. pp. 234–238.

[2] *The Anthocyanin Pigments of Plants*, Cambridge 1916, p. 153.

will simply compare the results of the crosses of three kinds of white by orange :—

	F_1	F_2
I. Orange × White-I	Orange	3 oranges : 1 white. (Cross I).
2. „ „ „ II	Magenta	9 magentas : 3 oranges : 4 whites. (Cross VI)
3. „ „ „ III	Orange	9 oranges : 3 pseudo-whites : 4 whites

Colours of Vegetative Organs and Floral Parts.

In all varieties of *Portulaca* the colour of vegetative organs, as stems and leaves on the one hand, and that of floral parts, as petals, filaments, styles, stigmas on the other, are intimately correlated to each other. In white-I stems, leaves, and styles are green ; and petals, filaments, styles, and stigmas are white. In white-II stems and leaves are green, and whilst filaments, styles, stigmas, and petals are also white, petals have sometimes a few broad or narrow magenta stripes or spots, and there may be few magenta filaments mingled with white ones. In all coloured varieties stems and leaves are reddish green ; filaments and styles are red or magenta, and so are also stigmas, though less intensely than in the latter. Ovaries are green, because their wall contains chloroplasts, and in coloured varieties they are somewhat reddish, but so slightly as to easily escape the notice of casual observers. When a coloured flower is produced on a white plant (*bud-mutation*) the branchlet bearing such a flower as well as leaves on it are more or less reddish, whilst other branchlets remain green. The pseudo-white race seems to deviate from this rule, because while leaves and stems are reddish, the corolla is white, but in reality the latter is not perfectly white, being tinged with magenta.

From the facts above given we may conclude that the factor C either alone or in conjunction with R (with or without B) is able to give colour to stems, leaves, petals, filaments, styles and stigmas. In white-II R and B are unaccompanied by C, and consequently are able to give colour, neither to stems and leaves, nor to petals, filaments, styles and stigmas, but sometimes

able to produce colour in a small segment of a petal, or in certain few filaments.

The peculiar condition in pseudo-white seems, as far as my observation goes, to be due to a special factor; the discussion on the latter will be reserved for a future paper.

Mutations, etc.

As the readers must have often noticed in the course of my description of the various crossing experiments we find not unfrequently a number of unexpected individuals among the offspring of certain crosses: thus, for instance, few magenta or orange plants are often seen among the progeny derived from seeds taken on selfed flowers of white parents, etc. At the beginning of my experiments it was thought that since seeds of *Portulaca* are very fine we might then have the chance admixtures from coloured plants, though not very probable in view of the utmost care taken for avoiding such. As the experiments progressed on the cases where unexpected individuals are detected have increased to such an extent that we came finally to the conclusion that they are clearly no chance admixtures, but normal products. Though seed-pans were placed near each other they were never watered from above, and so we must have avoided the danger of hurling down seeds of one pan to the neighbouring by this process. Nor would it be very probable that seeds were blown down from one pan to another by wind, since the earth in pans was held constantly moist by keeping them in a vessel partly full of water. If some coloured individuals detected among the progeny from white parents were really derived from pans containing seeds taken on coloured parents (by wind, etc.) no such fact will certainly occur, were pans containing seeds of both kinds kept distantly from each other. The following experiment made in 1920 may be of some interest: pans which contain seeds of whites on the one hand and those which contain seeds of coloured plants on the other were kept in some spots of our Botanical Garden where *Portulaca* was never cultivated before (thus avoiding the invasion of seeds of the former cultivation) and which are nearly 30 metres distant from each other and separated by fourfold high fences. In spite of all these treatments I have found as usual several coloured plants among the progeny of white parents.

Unexpected individuals are mostly dominant forms derived from recessive ones. These phenomena are, as I think, to be explained chiefly by the so-called "reverse mutations" or simply "reversions," by which I mean the return of a form to its original form from which it has been derived by mutation.[1] As the magenta variety of *Portulaca* will in all probability be the original wild form, from which other colour-varieties have been derived by mutation (so-called "loss-mutation") by one or several steps, such process, as the production of magentas or reds from whites is to be called a "reverse mutation." As I am just beginning to study such phenomena in *Portulaca* the explanations given below which are yet largely hypothetical and provisional are merely trials for indicating some possible ways of such changes. Many breeding experiments would of course be necessary in order to settle the question definitely.

Though in the course of my description all such cases met with were generally denoted with an *, they are collected below in the Table VIII. Each of them is prefixed with an * ; those without an * are presented here for the first time.

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[1] Reversions in the meaning here employed have been studied in *Antirrhinum majus* (DE VRIES, *die Mutationstheorie*, Bd. 1, p. 494), *Mirabilis Jalapa* (CORRENS, *Ber. d. Deutsch. Bot. Ges.*, Bd. 28 ; 1910, pp. 418–434), *Zea Mays* (EMERSON, *Amer. Naturalist*, Vol. 51, 1914, pp. 87–115 ; *Genetics*, Vol. 2, 1917, pp. 1–35), *Oryza sativa* (TERAO, *Amer. Naturalist*, Vol. 51, 1917, pp. 690–698), and *Plantago major variegata* and *contracta* (IKENO, *Genetics*, Vol. 2, 1917, p. 413 ; *Revue générale de Botanique*, Tome 52, 1920, pp. 49–56).

TABLE VIII.[1]

The following abbreviations are used in this Table:—M = magenta, R = red, O = orange, F = flesh-coloured, P = pseudo-white, W = white. The genetical formula placed between parentheses is that of the respective parent plant which I think to be probable.

No	Cross	F_1	F_2	F_3	F_4
* 1	White-I × orange		O (CCrrbb)	1M + 1R + 52O	
2	„ „ „		O (CCrrbb)	R (CCRrbb)	2M + 35R
3	White-I × orange			W (ccrrbb)	1M + 15W
4	„ „ „			W „	2R + 14W
5	„ „ „		W (ccrrbb)	M (CCRRBB)	32M
6	„ „ „		W(„)	O (Ccrrbb)	3O + 3W
7	„ „ „		W(„)	O(„)	1M + 1R + 4O
8	„ „ „		W(„)	M (CCRRBb)	163M + 22R
* 9	Yellow × white-I		O (CCggrrbb]	1M + 22O	
*10	Red × orange		O (CCrrbb)	1R + 3O	
*11	„ „ „		O(„)	2R + 5W	
*12	White-I × magenta		W (ccrrbb)	1O + 13W	
*13	„ „ „		W(„)	1O	
*14	White-II × magenta	M (CcRrBb)	17M + 1O + 18W		
*15	„ „ „	M „	10M + 1O + 2W		
*16	„ „ „		M (CcRRBB)	28M + 13W + 1O	
*17	„ „ „		M(„)	1M + 23W + 1F	
*18	„ „ „		M „	22M + 3W + 1P	
*19	„ „ „		M (CCRRBB)	35M + 1F + 1O	
*20	„ „ „		M (CCRRBB)	12M + 5R + 2F	
*21	„ „ „		W (ccRRBB)	2M + 42W	
*22	„ „ „		W(„)	5M + 77W	
*23	White-II × orange		M (CCRRBB)	75M + 42R	
*24	„ „ „		M (CcRrBb)	28M + 2R + 3O + 11W	
*25	„ „ „		O (CCrrbb)	1R + 1O	
*26	„ „ „		O (Ccrrbb)	1M + 1O + 2W	
*27	„ „ „		O (Ccrrbb)	12M + 2R + 45O + 3W	
*28	„ „ „		W (ccrrbb)	7M + 5O + 12W	
29	Magenta × orange			O (CCrrbb)	1M + 118O + 58W
*30	„ „ „			R (CCRrbb)	1M + 32R + 9O

[1] The production of oranges in white-II × magenta F_1 is enumerated in this Table (Nos. 14-15), but not discussed, inasmuch, as already spoken, they might be due to the contamination from other families (s. p. 106).

All cases mentioned in the above Table (with some exceptions) may be explained according to one of several ways discussed below, either alone or combined.[1]

1. *Reversion during the Formation of Gametes*—Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 21, 22, 25, 26, 27, 28 and 30 in the above Table may be included here. All of them are explainable when we will assume a certain reversional change of allelomorphs in cells concerned in the formation of gametes, either male or female. The question, in what stage of development such a change will take place cannot be yet exactly answered, but its occurrence might be perhaps sought in the reducing division leading to their formation, especially in synapsis stage. In some cases the reversion of one single allelomorph into its corresponding suffices to explain the phenomenon, but in others that of two or even three allelomorphs must be assumed.

To begin with the simplest case: the white of the constitution **ccrrbb** produces normally the gametes **crb**; suppose that the reverse mutation of the allelomorph **c** into **C** takes place in some cells concerned in the reducing division, then the gametes **Crb** will be produced besides the normal ones **crb**. Since the number of the mutated gametes is certainly very small as compared to that of normal ones the gametes **Crb** will meet in fertilisation most commonly with **crb**, though very exceptionally the meeting of the mutated male and female gametes **Crb** might occur; the resulting zygotes are phæno-typically the same in both cases, viz. orange, but genotypically different, viz. **Ccrrbb** in the first and **CCrrbb** in the second case. The production of oranges from whites, as seen in Nos. 6 (F_3), 7 (F_3), 12, and 13 may be due to such a reverse mutation. For instance, in No. 6 one orange has been derived in F_3 from the seed taken on a F_2 white plant, and that orange was found to segregate in F_4 into 3 oranges : 3 whites, proving thus itself to be of the constitution **Ccrrbb**, though here the actual numbers of the two kinds of segregates in F_4 do not very well agree with the calculated (4·5 : 1·5), evidently on account of the small number of individuals. No. 12 might

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[1] What are given below are, as above stated, mere trials to explain the appearance of unexpected individuals, and would contain necessarily some defects and mistakes, especially as the very poor germination of seeds makes the explanation difficult, and in certain cases even almost impossible. It would be quite possible that in future some of them might be replaced by much better ones.

perhaps belong to this category, though the behaviour of the F_1-oranges in F_2 was not yet examined; so will be perhaps also No. 13, where however no seed of white came to germination.—The production of some reds from homozygous oranges, as seen in Nos. 1, 2 (F_2), 10, and 25 is also explainable by assuming the reversion of one allelomorph, viz. the formation of some gametes **CRb** besides normal **Crb**, and the occurrence of the fertilisation **CRb × Crb** or **CRb × CRb** (or their reciprocal), giving rise to red zygotes of the composition **CCRrbb** or **CCRRbb**.—The production of magentas from whites, as seen in Nos. 21 and 22 might also be due to the reversional change of one single allelomorph; since the F_1-whites in those two Nos. are derived from the cross white-H × magenta, and consequently should possess the genotypic composition **ccRRBB** its normal gametes are **cRB**, and thus the formation of few gametes **CRB** by means of the reversion of **c** into **C**, and the mating of the latter, either with normal gametes **cRB** or the mutated **CRB** themselves will give rise to magenta zygotes, hetero- in the first and homozygous in the second case.—In No. 2 (F_1) we see the production of magenta from red, and this is also evidently a simple process consisting in the reversion of one **b** into **B**, the development of few gametes **CRB** as the consequence, and the fertilisation **CRB × CRb** or its reciprocal.

In the production of magentas from oranges, as seen in Nos. 1 and 9, as well as that of reds from whites, as seen in No. 4, the occurrence of a simultaneous reversion of two allelomorphs should be necessarily assumed. Thus in the first of two cases just cited the orange of the composition **CCrrbb** must produce the gametes **Crb** (normal) and **CRB** (mutated), and in the second the white **ccrrbb**, the gametes **crb** (normal) and **CRb** (mutated)[1]

The reversion process in No. 27 may be explained as follows:—the orange parent is here heterozygous, i.e. of the composition **Ccrrbb**; since normally the gametes **Crb** and **crb** (either male or female) are produced in equal numbers their meeting will give rise to 3 oranges : 1 white, so that if magentas and reds segregated out in this case are considered to be oranges

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[1] The formation of the gametes of two kinds, viz **CRb** and **CrB** in the first case, and that of **Crb** and **cRb** in the second will lead to the same results, but then the fertilisation between the two mutated gametes. viz **CRb × CrB** as well as **Crb × cRb** (or their reciprocal) must be assumed to have occurded

we have $12 + 2 + 45 = 59$ oranges and 39 whites (expected, $66.75 \pm 4 : 22.25 \pm 4$). The production of some magentas and reds in this case may be explained if we will assume that a certain number of the gametes of the composition CRB, and CRb have arisen on account of the reversion of one or two allelomorphs, and the fertilisation, such as $CRB \times Crb$, $CRB \times crb$, $CRb \times Crb$ $CRb \times crb$ have taken place. Almost the same might perhaps be said in respect to No. 26, though it contains too few individuals to lead us to a somewhat probable conclusion (compare Table VIII, that No.) The result of No. 30 may be explained in an almost similar way ; its normal gametes are CRb and Crb, and we have 33 reds and 9 oranges, expected 31.5 ± 2.8 and 10.5 ± 2.8, if we will reckon 1 magenta among the reds ; this magenta was produced because at least one gamete CRB has arisen by reversion.

In respect to the production of magentas from whites, as we see in Nos. 3, 5 (F_3), 8 (F_3), and 28 we must assume the simultaneous reversion of three allelomorphs c, r and b into C, R and B respectively, though here on account of the complete linkage of R and B the whole process will be reduced to the reversion of one factor and one factor-complex. Suppose that on account of this process few gametes CRB are produced besides normal ones crb ; the fertilisation between CRB and crb which will be the most prevailing one will give magenta of the constitution $CcRrBb$, whilst very rarely the fertilisation $CRB \times CRB$, i.e. that between two mutated male and female gametes might take place. To the latter category may belong No. 5, because here the magenta produced in F_3 from a seed taken on 1 white F_2 plant seems to breed true in F_4, the offspring in the latter generation consisting wholly of magentas (32 in all), though it would not be impossible that all other segregates did not come to germination.

In No. 28 few oranges and magentas were produced from whites of the composition $ccrrbb$. Here it must be assumed that a small number of gametes of two kinds, viz. Crb and CRB were simultaneously produced besides normal ones crb, and that the fertilisations $Crb \times crb$ as well as $CRB \times crb$ (or their reciprocal) have take place.

In No. 8 1 magenta derived in F_3 from 1 F_2 white was found to segregate into 103 magentas and 22 reds, whence it may be inferred that this magenta parent might be of the constitution $CCRRBb$, though the

actual number of the two kinds of segregates does not very well agree with the expected (expectation on $3:1$ basis, $93\cdot75\pm4\cdot8:31\cdot25\pm4\cdot8$). How the magenta of such composition has arisen from the white cannot yet be determined, and though its origin might be perhaps inferred this is merely a matter of conjecture, and it would not be worth while to state here such an inference.

II. *Reversion in the Somatic Cell.*—To this class belongs No. 11 in Table VIII. Suppose that the reverse mutation has occurred in a certain somatic cell of the composition $CCrrbb$, at least one cell-generation before the reducing division, and suppose further that this cell has got the composition $CCRrbb$ in consequence of this process. From the latter cell the male and the female gametes CRb and Crb will be derived after one or more cell-generations according to different cases. The fertilisation between them will give rise to zygotes consisting of 1 $CCRRbb$, 2 $CCRrbb$ and 1 $CCrrbb$; the production of 20 reds and 5 oranges in No. 11 may be due to such a process (expected $18\cdot75\pm2$ and $6\cdot25\pm2$).

III. The mutations described in I and II are, as already stated, the reverse ones, i.e. those from recessive to dominant condition. The mutations in the opposite sense, i.e. those from dominant to recessive condition (so-called "loss-mutation") have been also observed sometimes, though not frequently, to which might belong Nos. 23 and 29 in Table VIII. In No. 29 one orange which should be theoretically homozygous, i.e. $CCrrbb$, has produced 1 magenta, 118 oranges, and 58 whites. According to our hypothesis a certain somatic cell having the genotypic composition $CCrrbb$ has undergone a "loss-mutation," and changed into $Ccrrbb$; the gametes Crb and crb are derived from it after a number of cell-generations, and their free assortment has given rise to oranges and whites in the approximate ratio $3:1$ (119 oranges : 58 whites, theoretically $132\cdot75\pm5\cdot8:44\cdot25\pm5\cdot8$, if we will count 1 magenta as orange; 1 magenta was produced at the same time, perhaps because 1 gamete CRB has arisen by reversion of b into B. Thus the whole process in No. 29 consists in loss-mutation and reversion combined.

No. 23 (magenta) was found to segregate in F_1 into magentas and reds, whence we might at once be led to the assumption that that magenta parent should have the composition $CCRRBb$ (75 magentas : 42 reds, expected $87\cdot75\pm4\cdot7:29\cdot25\pm4\cdot7$). Since however this parent has been originally derived

from white-II – orange, and since we see there the complete linkage between the factors R and B, it would not be probable that it has had that composition from the very beginning; in all probability it has been at first of the constitution $CCRRBB$, changed into $CCRRBb$ by a "loss-mutation", and then undergone the segregation above stated.

In all cases under I above enumerated (and in some cases under III) I have assumed that the reversion takes place during the formation of gametes, but it would be equally possible that this process of mutation occurs, not during the gametic formation, but some time before in the somatic cell. To cite one instance for illustrative purpose, in No. 6 (Table VIII) where white-I ($ccrrbb$) gives rise to orange of the constitution $Cerrbb$ the process may be as follows:—a somatic cell of the constitution $ccrrbb$ gets that of $Cerrbb$ by reversion; such cell produces during each succeeding cell-division the cells $Cerrbb$, so that in the reducing division the gametes of the constitution Crb and crb are formed. (Compare the discussion in p. 124. If what is above described be true the whole process of reversion in I (and also in some cases under III) is essentially identical with that in II. To determine exactly in each individual case which alternative will be realised, i.e. whether the reversion occurs in the somatic cell or first in the formation of gametes would be an almost impossible task in the present state of our knowledge.

IV. Each of the F_2 magenta parents in Nos. 16, 17 and 18, derived from the cross white-II × magenta has segregated into magentas and whites, and produced in addition 1 orange, 1 flesh-coloured and 1 pseudo-white. As this segregation has given rise to 90 magentas and 42 whites in total, i. e. $99 \pm 4 \cdot 97$ and $33 \pm 4 \cdot 97$ respectively on $3 : 1$ expectation we may in all probability regard each magenta parent in our case to be of the constitution $CcRRBB$. The question, however, to what kind of mutation will be due the production of flesh-coloured and pseudo-white plant in this case would be quite unexplainable, especially as the exact genotypic composition of the two latter is yet unknown.

In respect to Nos. 19 and 20 we may consider that the F_2 magenta parent is homozygous, i.e. of the constitution $CCRRBB$ and has bred true

in F, (35 and 12 magentas produced respectively). The orange and the red found in addition have probably been produced by the "loss-mutation", but as to the mode of production of flesh-coloured plants we are in the same position as in respect to Nos. 17 and 18 just cited, and consequently we are not able to make any surmise about it.

V. *Change of the Linkage Ratio.* In No. 24 we see that one magenta ex white-11 × magenta segregates into 28 magentas, 2 reds, 3 oranges and 11 whites. We may consider this magenta parent to have had the composition **CcRrBb**, and the appearance of 2 reds which have never been met with in F_2-generation (with one exception, s. the Table VI, A) is, as I think, due to the change of the *complete* linkage between **R** and **B** into a *partial*, as we have seen in the Cross VIII. Suppose that **R** and **B** are linked according to the series $n : 1 : 1 : n$; since no such relation exists between **C** and **R** or between **C** and **B**, we should have the eight following classes of gametes in the ratios indicated, viz.:—

$$n\boldsymbol{CRB} + n\boldsymbol{cRB} + 1\boldsymbol{CrB} + 1\boldsymbol{crB} + 1\boldsymbol{CRb} + 1\boldsymbol{cRb} + n\boldsymbol{Crb} + n\boldsymbol{crb}.$$

The mating of male and female gametes of such constitutions should give rise to the four following kinds of zygotes in the ratios indicated, viz.:—

Magenta	Red	Orange	White
$9n^2 + 12n + 6$	$6n + 3$	$3n^2 + 6n + 3$	$4n^2 + 8n + 4$

Though the number of individuals in No. 24 is rather small, the following calculations were made. Since we have observed in the Cross VIII the linkage between **R** and **B** belonging to the series $5 : 1 : 1 : 5$ or $6 : 1 : 1 : 6$, I have put $n = 5$ or 6, and then we have in respect to the expected number of individuals for each kind of zygotes.

	Magenta	Red	Orange	White	Totals
$n = 5$	$22 \cdot 23 \pm 3 \cdot 3$	$2 \cdot 52 \pm 1 \cdot 5$	$8 \cdot 25 \pm 2 \cdot 6$	$11 \cdot 00 \pm 2 \cdot 9$	44
$n = 6$	$22 \cdot 56 \pm 3 \cdot 3$	$2 \cdot 19 \pm 1 \cdot 4$	$8 \cdot 25 \pm 2 \cdot 6$	$11 \cdot 00 \pm 2 \cdot 9$	44
Actual	28	2	3	11	44

The agreement between the theoretical and the actual numbers is not very bad in both cases in view of the small number of plants, except in respect to the orange where the number of individuals is much smaller than might be expected theoretically ; this may be due possibly to the fact that a comparatively large proportion of seeds of this class of zygotes failed to germinate. The further behaviour of one of the two reds segregated out in F_3 was ascertained, because I could get seeds on it by selfing. It has produced in 1919 the F_4-offspring containing 1 magenta, 28 reds, 12 oranges and 17 whites, thus proving itself to be heterozygous. We may consider the red examined to have been of the constitution $CCRrbb$,[1] and that it has changed into $CcRrbb$ before the formation of gametes ; the male and the female gametes CRb, cRb, Crb, crb are formed, and their mating has given rise to 29 reds : 12 oranges : 17 whites, theoretically $32 \cdot 6 \pm 3 \cdot 8 : 10 \cdot 9 \pm 3 \cdot 0 : 14 \cdot 5 \pm 3 \cdot 8$ on $9 : 3 : 4$ basis, if we will count 1 magenta as 1 red ; 1 magenta was formed because at least one gamete CRB was produced by reversion, so that the whole process consists, exactly as in No. 29 (Table VIII, discussion p. 127), in the " loss-mutation " combined with reversional change.

In the Table VI, A (p. 109) we have seen that the F_2-offspring ex white-II × orange No. 2 contains 81 magentas, 20 oranges, 34 whites and 1 red, 136 in all. They are the total of all the offspring derived from 12 F_1-plants by selfing. Of these 12 families of the F_2-offspring 11 contain no red at all, so that the one red under discussion belongs to one family composed of only 7 plants, viz. 5 magentas, 1 red and 1 orange.[2] The occurrence of 1 red in this family might perhaps be due to the partial linkage similar to that in the case just stated above, but no sure conclusion can be drawn here on account of the small number of individuals.

Bud-mutations have been observed, though not frequently. They are below simply described, but no discussion will be made, this being impossible

---

[1]   Since the factors R and B were linked according to the series $5 : 1 : 1 : 5$ or $6 : 1 : 1 : 6$ in the preceding generation, we should have in the present case the reds of the composition $CCRrbb$ and $CCRRbb$ in the ratio $10 : 1$ or $12 : 1$ respectively, and it is quite natural that we have now $CCRrbb$, because only two reds were examined.

[2]   Whites are wanting in this small family, perhaps because all seeds which will give rise to whites failed to germinate.

on account of the small number of the cases which I have encountered till now.

1. One white plant derived ex orange × white-I (Table 1, p. 98) has produced besides white flowers some orange-coloured ones. Two of the latter were selfed, and seeds thus obtained have given rise in the next year to 14 plants which have borne, not orange flowers as was expected, but white ones simply. Some white flowers on the original plant were selfed, but seeds got from them did not germinate. As the second generation did not bear orange flowers, the phenomenon will not belong properly to bud-mutation.

2. One white F_1-plant derived ex white-I × orange has produced one branchlet bearing orange flowers. These as well as one white flower were selfed. Only two seeds from the former came to germination, and one of the plants thus produced has so far developed as to bear one flower which was *magenta*; three seeds taken on the white flower had germinated and developed to 2 *magentas* and 1 *orange*.

3. One white plant among the F_1-offspring ex red × white-1 has borne 2 white flowers and 1 magenta one. No seeds could be obtained from the former, but those got on the latter has produced in the next year 3 plants, viz. 2 magentas and 1 white, thus the magenta flower was proven to have been heterozygous in its genotypic constitution.

4. One white plant among the F_1-progeny ex white-II × magenta has borne besides white flowers one magenta one in 1920. Whether the latter is homo- or heterozygous will be examined in this year, because I have got seeds on this flower.

Summary.

1. All coloured varieties of *Portulaca grandiflora* are characterised by possessing the factor C.

2. C alone gives rise to *orange* flower-colour. C and G produce together *yellow* flower-colour, C and R together red; whilst the *magenta* colour is due to the co-operation of the three factors, C, R and B.

3. As to the genetics of *flesh-coloured* and "*pseudo-white*" races my experiments are not so far advanced as to be able to fully establish their respective genotypic constitution.

4. All *cc*-plants are white. There are three kinds of whites, which I call *I*, *II* and *III* respectively. The *white-I* (***ccrrbb***) possesses perfectly white floral parts, while the *white-II* (***ccRRBB***) may produce few magenta stripes or spots on petals and few magenta filaments. The *white-III* is externally perfectly similar to the *white-I*, but is characterised by producing in certain crosses a number of the so-called " pseudo-white," in all probability according to Mendelian rule ; its genotypic constitution is yet unsettled.

5. The factors *R* and *B* are generally in *complete* linkage or " coupling," and act like one single factor, but sometimes it changes into a *partial*, causing the production of a certain number of unexpected *red* individuals.

6. The colour of vegetative organs and floral parts are correlated to each other.

7. A small number of unexpected individuals of several kinds may often be produced, thus for instance, magenta or red, etc. is found among the offspring of orange or white parent (selfed!) I have tried to explain such phenomena chiefly (but not all) by means of " reverse mutations."

8. Bud-mutations were also observed.

EXPLANATION OF PLATE II.

All figures are from water-colour drawings from nature

Fig. 1.   Magenta

Fig. 2   Red

Fig. 3   Orange.

Fig. 4.   Yellow.

Fig. 5.   Flesh-coloured.

Fig. 6.   Pseudo-white.

Fig. 7.   White-II.   Magenta stripes on some petals!

Fig. 8.   White-I.

1

2

3

4

5

6

7

8

N.MIZUSHIMA

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CONTENTS.

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All communications relating to this Journal should be addressed to the
Director of the College of Agriculture.

List of Lepidoptera of the Islands Tanegashima and Yakushima.

By

Nobukatsu Marumo.

With Plate III.

The four great islands that constitute Japan proper are mostly included within the palaearctic region, though insects belonging to the oriental region are also richly found over these islands. Especially in southern parts, i.e. Kii of Honshiu, Tosa of Shikoku as well as Hyuga, Osumi and Satsuma of Kiushiu, the characteristics of the latter region are emphasized.

Two small islands Yakushima and Tanegashima belonging to Kagoshima Prefecture, forming Kumage District, lie about 60 miles off southwards from Kagoshima City, though the distance between the headland of Sata of Kiushiu and the nearest spot of Tanegashima is at most within 30 miles. Notwithstanding the approachment of these islands and Kiushiu there is a great difference in their flora: there are found a good deal of tree-ferns throughout the wood and the banians on their coast of the former. The mangroves are also seen growing at the mouth of the Kuma river of Tanegashima.

Although the plants of Tanegashima are almost all in common with those of Yakushima, it is very characteristic that the pine-trees are almost entirely wanting in the latter in which they are replaced by the well-known Cryptomeria trees, called "Yakusugi." The island Yakushima is about 15 miles in the distance across, in the centre of which a steep high granitic mountain called Miyanoura (about 1900 m.) arises, while the island Tanegashima is a long table-land (about 35 miles long) without remarkable mountains.

The difficulty of separating the flora of the islands, also exists in the study of their insect fauna, and investigating the lepidopterous insects of the two islands I could come to the conclusion that in the fauna the two islands

just stand between those of Kiushiu and Loochoo Islands* (belong to the oriental region), rather nearer situating to the former than to the latter.   IWATA who had studied the butterflies of this district (Tanega-shima and Yakushima) stated that the boundary line between the Loochoo Islands and Kiushiu probably lie southwards from these islands.   I can express my agreement with his opinion.   The oriental lepidopterous insect such as *Hebomoia glaucippe, Junonia almana, J. orithya, Nacaduva atrata, Melanitis phedisma* and the species of the genera, *Callidula, Doratoptera* and *Nyctemera* are represented in this district, and no species belonging to the genera *Hebomoia, Callidula* and *Doratoptera* which are considered to have origin in the oriental region have hitherto been found in Japan proper.   But the most lepidopterous insects distributed over these islands are common with those found in the four great islands of Japan and the local form of species comes nearer to that of the palæarctic than to the oriental region.   These facts indicate me the faunal feature of this district.

As I have been interested in the insect fauna of this district I made repeated excursions to these islands, one in July 1918 and the other in June 1919.   In addition to mine the late Dr. T. MIYAKE made a collecting in August 1909 and the late Mr. K. HABUTSU in September 1910.   All these materials collected by these two gentlemen have also been placed at my disposal.

The total number of species enumerated in this paper is 179, of which 45 are Rhopalocera and the rest 134 are Heterocera, of which 7 appear to be new to science and their descriptions are given in their proper systematic position.   Several examples collected which are undetermined, are not enumer-ated in this paper.   I must express my hearty thanks to the late Dr. T. MIYAKE who offered generously his private list to my study.

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* Including Amami Oshima.

Fam. **Lithosiadæ.**

Subfam. NOLINAE

Nola trilinea. n. sp.

(Pl. III, fig. 1.)

♂. White. Palpi brown at sides. Antennæ bipectinate to before apex. Forewings with the costa brown; terminal area suffused with brown; crests of scales at middle and at upper angle of cell slightly tinged with brown; antemedial line slight, brown, angled outwards in cell; medial line brown, distinct from lower angle of cell to inner margin; postmedial line brown, more or less punctiform, excurved below costa and at vein 5; subterminal line very indistinct, suffused with brown on its inner side; cilia brownish with a dark line through them. Hindwings white suffused with brownish towards termen; cilia brownish. Underside whitish; forewings more or less strongly and hindwings slightly suffused with brownish fuscous.

Expanse 18 mm.

A male type taken by me at Noma, Tanegashima, July 11, 1919.

Subfam. LITHOSIANAE.

Lexis immaculata.

Katha immaculata Butl. P.Z.S. 1880, p. 671; Kirby, Cat. Het. p. 329; Leech, Trans. Ent. Soc. 1899, p. 184; Hmpsn. Cat. II. p. 118, pl. 21. f. 8.

A male taken by me at Miyanoura, Yakushima, July 12, 1918.

Local distribution. Kiushiu (Nagasaki, Yakushima); Honshiu?

General distribution. Japan; Corea; Formosa; Malay.

Ilema affincola.

Lithosia affincola Brem. Lep. Ost—Sib. p. 97, pl. 8. f. 5 (1864); Seitz, Seitz, Macrolep. II. p. 67, pl. 12 k; Hmpsn. Cat. Suppl. I. p. 504.

Manula calamaria Moore, P.Z.S. 1878, p. 18.

Katha aprica Butl. Cist. Ent. III. p. 115. (1885).

Ilema sororcula Hmpsn. (part). Cat. II. p. 185 (1900).

A male and a female of *aprica* form taken by me at Nishinoomote, Tanegashima, July 25 and 26, 1918.

Local distribution. Hokkaido; Honshiu.

General distribution. Japan; Loochoo; China; Siberia; India.

Asura intermedia. n. sp.

(Pl. III. fig. 2.)

Yellow. Thorax without black points; fore tibiæ and tarsi banded with black at the tip. Forewings with a black point at base; subbasal and curved antemedial series of black points; a medial oblique series of black points; a highly and irregularly dentate postmedial black line strongly bent outwards below costa and to inner margin, with long teeth on veins 4, 6 and 7; a subterminal series of black points, the spot on vein 4 is situated near termen. Hindwings hyaline slightly suffused with yellow.

Expanse ♂ 18, ♀ 21 mm.

A male type taken by me at Miyanoura, Yakushima, July 12, 1918. Several males and females also from Yakushima, July 1918.

Closely allied to *Asura obsoleta* Moore.

Subfam. ARCTIANÆ.

Diacrisia subcarnea.

Spilosoma subcarnea Walk. Cast. III. p. 675 (1855); Butl. Ill. Het. B.M. III.
    p. 6, pl. 42. f. 8; Leech, Trans. Ent. Soc. 1899, p. 149; Hmpsn. Cat.
    III. p. 215; Seitz, Seitz, Macrolep. II. p. 85, pl. 15 d.

Aloa bifrons Wlk. Cat. III. p. 705 (1855).

Aloa leucothorax Feld. Wien. ent. Mon. VI. p. 36 (1862).

Spilosoma erubescens Moore, A.M.N.H. (4) XX. p. 89 (1877).

Spilosoma rybakowi Alph. Rom. Mém. IX. p. 174, pl. 10. f. 9 (1897).

Hyarias oberthuri Semp. Schmett. Phil. II. p. 489 (1899).

Two males and females taken by HABUTSU in Yakushima, August 1910. Local distribution. Honshiu; Kiushiu.

General distribution. Japan; Loochoo; Formosa; Corea; China; Philippines; Celebes.

Utetheisa pulchella.

Tinea pulchella Linn. Syst. Nat. 10 ed. p. 534 (1758); Kirby, Cat. Het. p. 346; Leech. Trans. Ent. Soc. 1899, p. 179; Staud. Cat. ed. p. 373; Hmpsn. Cat. III. p. 488, Seitz, Seitz, Macrolep. II. p. 73, pl. 13 k.

Noctua pulchra Den. et Schiff. Wien. Verz. p. 68 (1776).

Geometra lotrix Cram. Pap. Exot. II. pl. 109, E, F (1779).

Deiopeia pulchella var. *candida* Butl. Trans. Ent. Soc. 1877, p. 361.

Deiopeia thyster Butl. Trans. Ent. 1877, p. 361.

Utetheisa pulchella ab. *pallida, fasciata, semisignata, melampyga* Spuler, Schmett. Eur. II. 143 (1910).

Utetheisa pulchella f. *nuella* Seitz, Seitz, Macrolep. II. p. 73, pl. 13 k.

Many specimens of *nuella* form taken by me at Nishinoomote, Tanegashima, July 26 and 28, 1918. They aggregated on the flowers of *Vitex trifolia* grown on the coast of Tanegashima.

Local distribution. Honshiu; Kinshiu.

General distribution. Japan; Loochoo; Formosa; China; India; Philippines; Malay; New Guinea; Australia; Europe etc.

Fam. **Noctuidæ**.

Subfam. HADENINÆ.

Cirphis flavostigma.

Xanthia flavostigma Brem. Lep. Ost – Sib. p. 52, pl. 5. f. 11 (1864); Leech, Trans. Ent. Soc. 1900, p. 123; Hmpsn. Cat. V. p. 509; Warren, Seitz, Macrolep. III. p. 96, pl. 24 e.

Leucania singularis Butl. A.M.N.H. (1) 1. p. 80 (1878), Ill. Het. B.M. II. p. 22, pl. 28. p. 11.

A female taken by me on Mt Miyanoura, Yakushima, July 16, 1918.

Local distribution. Hokkaido; Honshiu; Kinshiu.

General distribution. Japan; Corea; Formosa; China; Siberia; India.

Subfam. ZENOBIANÆ.

Delta intermedia.

Cloantha intermedia Brem. Lep. Ost—Sib. p. 53, pl. 5. f. 13 (1864) ; Hmpsn.
    Cat. VIII. p. 192 ; Warren, Seitz, Macrolep. III. p. 202, pl. 42 c.
Auchmis sikkimensis Moore, P.Z.S. 1867, p. 49, pl. 6. f. 15.
A male taken by me at Nishinoomote, Tanegashima, July 26, 1918.
Local distribution. Honshiu ; Kiushiu.
General distribution. Japan ; Siberia ; India.

Subfam. ERASTRIANÆ.

Phyllophila obliterata.

Anthophila obliterata Rmbr. Ann. Soc. Ent. Fr. 1833, p. 27, pl. 2. f. 17 ;
    Staud. Cat. pal. p. 230 ; Hmpsn. Cat. X. p. 383 ; Warren, Seitz, Macrolep.
    III. p. 274, pl. 51 k.
Anthophila wimmerii Treit. Eur. Schmett. X. 2, p. 148 (1835).
Anthophila recta Ev. Faun. Volg. Ur. p. 338 (1844).
Phyllophila cretacea Butl. Ill. Het. B.M. III, p. 28, pl. 47. f. 11 (1879).
    A male of *cretacea* form taken at Miyanoura, Yakushima. July 12, 1918.
    Local distribution. Honshiu ; Kiushiu.
    General distribution. Japan ; Corea ; China ; Siberia ; Persia ; Europe.

Lithacodia signifera.

Acontia signifera Wlk. Cat. XII. p. 793 (1857) ; Moore, Lep. Ceyl. III. p.
    47, pl. 150. f. 4 ; Leech, Trans. Ent. Soc. 1900, p. 145 ; Hmpsn. Cat.
    X. p. 504 ; Warren, Seitz, Macrolep. III. p. 276, pl. 51 m.
    A male taken by me at Kosugitani, Yakushima. July 20, 1918.
    Local distribution. Honshiu ; Kiushiu.
    General distribution. Japan ; Corea ; China ; India ; Australia.

Naranga æenescens.

Naranga æenescens Moore, P.Z.S. 1881, p. 359 ; Hmpsn. Cat. X. p. 632. pl.
    168. f. 3 ; Warren, Seitz, Macrolep. III. p. 282, pl. 51 n.

A male taken by me at Noma, Tanegashima, June, 16, 1919.

Local distribution. Honshiu ; Kiushiu.

General distribution. Japan ; Formosa ; China.

Subfam. PHLOGOPHORINÆ.

Phlogophora sinuosa.

Phalga sinuosa Moore, P.Z.S 1881, p. 375, pl. 37. f. 7 ; Hmpsn. Cat. XI. p. 17. f. 10.

Eutelia viridinota Swinhoe, Trans. Ent. Soc. 1895, p. 52.

A male taken by me at Kusukawa, Yakushima, July 20, 1918.

Local distribution. Honshiu ; Kiushiu (Yakushima).

General distribution. Japan ; Borneo ; India.

Subfam. CATOCALINÆ.

Catocala prægnax.

Catocala prægnax Wlk. Cat. XIII. p. 1213 (1857) ; Butl. Ill. Het. B.M. III. pl. 46. f. 11 ; Leech, Trans. Ent. Soc. 1900, p. 534 ; Hmpsn. Cat. XII. p. 165 ; Warren, Seitz, Macrolep, III. p. 317, pl. 57 c.

A female taken by me at Kaminaka, Tanegashima, June 12, 1919.

Local distribution. Hokkaido ; Honshiu ; Kiushiu.

General distribution. Japan ; Corea ; China ; Siberia.

Erebus crepuscularis.

Noctua crepuscularis Linn. Syst. Nat. 12 ed. I, 2. p. 811 (1767) ; Leech, P. Z.S. 1889, p. 544 ; Fritze, Faun. Liu-Kiu-Ins. p. 66 ; Hmpsn. Cat. XII. p. 292 ; Warren, Seitz, Macrolep. III. p. 322, pls. 58 d. 59 a.

Nyctipao ophiusperis Hübn. Verz. p. 272 (1827).

Nyctipao lætitia Butl. Ill. Het. B.M. III. p. 26, pl. 47. f. 9 (1879).

A female taken by me at Kusukawa, Yakushima, July 20, 1918.

Local distribution. Hokkaido ; Honshiu ; Kiushiu ; Shikoku.

General distribution. Japan ; Loochoo ; China ; Andamans ; Sumatra ; Borneo ; Philippines ; Java ; New Guinea.

Metopta rectifasciata.

Spirama rectifasciata Mén. Cat. Lep. Het. Mus. Petr. pl. 17. f. 6 (1863) ;
    Leech, Trans. Ent. Soc. 1900, p. 575 ; Hmpsn. Cat. XII. p. 301 ; Warren,
    Seitz, Macrolep. III. pl. 58 c, d.

Spirama japonica Wlk. (nec Guen). Cat. XXXIII. p. 918 (1865).

Spirama interlineata Butl. A M.N.H. (5) 1. p. 291 ; Ill. Het. B.M. II. p. 41,
    pl. 34. f. 2.

    Common in both Yakushima and Tanegashima.

    Local distribution.   Hokkaido ; Honshiu ; Kiushiu ; Shikoku.

    General distribution.   Japan ; Corea ; Formosa ; China.

Ophisma gravata.

Ophisma gravata Guen. Noct. III. p. 237 (1852) ; Hmpsn. Cat. XII. p. 542 ;
    Warren, Seitz, Macrolep. III. p. 328.

    A female taken by HABUTSU in Tanegashima, August 1910.

    Hitherto unrecorded from Japan.

    Local distribution.   Kiushiu (Tanegashima.)

    General distribution.   Japan ; Loochoo ; China ; Malay ; India.

Parallelia curvata.

Ophiusa curvata Leech, P.Z.S. 1889, p. 546, pl. 58. f. 8 ; Hmpsn. Cat. XII
p. 578 ; Warren, Seitz, Macrolep. III. p. 328, pl. 612.

    Four females taken by me at Jurokuban and Nona, Tanegashima, June
10, 11 and 15, 1919.

    Local distribution.   Honshiu ; Kiushiu.

    General distribution.   Japan ; Loochoo ; Corea.

Chalciope hyppasia.

Noctua hyppasia Cram. Pap. Exot III. pp. 99, pl. 250. f. E (1779) ; Leech,
    Trans. Ent. Soc. 1900, p. 567 ; Hmpsn. Cat. XIII. p. 27 ; Warren, Seitz,
    Macrolep. III. p. 332, pl. 61 f.

Phalaena deliana Stoll. Cram. Pap. Exot. V. pt 160, pl. 36. f. 4 (1790).

Ophiusa anfractuosa Boisd. Fam. Ent. Madag. Lep. p. 104, pl. 15. f. 6 (1833).

Trigonodes acutula Guen. Noct. III. p. 283, pl. 22. f. 6 (1852).

Trigonodes inacuta Guen. Noct. III. p. 284 (1852).

Trigonodes compar Wlk. Cat. XIV. p. 1451 (1858).

A female taken by me at Noma, Tanegashima, June 11, 1919.

Hitherto unrecorded from Japan.

Local distribution. Kiushiu (Yakushima).

General distribution. Japan ; Loochoo ; Formosa ; China ; Philippines ; Sumatra ; India ; Australia ; Africa etc

Mocis undata.

Noctua undata Fabr. Syst. Ent p. 600 (1775) ; Hmpsn. Cat. XIII. p. 91 ;
Warren, Seitz, Macrolep. III. p. 333, pl. 612.

Phalene archesia Stoll, Cram. Pap. Exot. III. p. 146, pl. 273. f. 14 (1870).

Ophiusa mayeri Boisd. Fam. Ent. Madag. p. 104 (1834).

Remigia pollito Guen. Noct. III. p. 319 (1852).

Remigia gregalis Guen. Noct. III. p. 320 (1852).

Remigia mutuata Wlk. Cat. XIV. p. 1505 (1858).

Remigia juglis Wlk. Cat. XIV. p. 1505 (1858).

Hypetra diffundens Wlk. Cat. XXXIII. p. 963 (1865).

Remigia associata Wlk. Cat. XXXIII. p. 1010 (1865).

Remigia inconcisa Wlk. Cat. XXXIII. n. 1913 (1865).

Remigia bifasciata Wlk. Cat. XXXIII. p. 1014 (1865).

Ophiusa subænescens Wlk. Proc. Nat. Hist. Soc. Glasg. I. p. 361, pl. 6. f. 9.
(1873).

Caminata undata subsp. *bifasciata* Warren, Seitz, Macrolep. III. p. 333 (1913).

A male taken by HABUTSU in Yakushima, August 1910.

Local distribution. Hokkaido ; Honshu ; Kinshu.

General distribution. Japan ; Corea ; Formosa ; China ; Philippines ; Java ;
India ; Africa.

Mocis anneta.

Remigia anneta Butl. A. M. N. H. (5) I. p. 293 (1878) ; Ill. Het. B. M. II. p.
43, pl. 34. f. 7 ; Leech, Trans. Ent. Soc. 1900, p. 564 ; Staud. Cat. Pal.

p. 240; Hmpsn. Cat. XIII. p. 102; Warren, Seitz, Macrolep. III. p. 334, pl. 61 g.

A male taken by me at Kusukawa, Yakushima, July 20, 1918.

Local distribution. Hokkaido; Honshiu; Kiushu; Shikoku.

General distribution. Japan, Corea; China; Siberia.

Subfam. PHYTOMETRINÆ.

Phytometra daubei.

Plusia daubei Boisd. Gen. et Ind. Meth. p. 159 (1840); Staul. Cat. pal. p. 289; Hmpsn. Cat. XIII. p. 477.

Plusia ciliaris Wlk. Cat. XII. p. 928 (1857); Butl. Ill. Het. B. M. VI. p. 36, pl. 110. f. 5.

A male specimen taken by MIYAKE.

Local distribution. Kiushiu (Tanegashima or Yakushima).

Hitherto unrecorded from Japan.

General distribution. Japan; India; Europe.

Subfam. NOCTUINÆ.

Thermesia ussuriensis.

Remigia ussuriensis Brem. Lep. Ost-Sib. p. 61, pl. 5. f. 19 (1864); Leech, Trans. Ent. Soc. 1900, p. 569; Warren, Seitz, Macrolep. III. p. 381, pl, 69 e.

Two females taken by me at Miyanoura, July 12, 1918.

Local distribution. Hokkaido; Honshiu; Kiushiu; Shikoku.

General distribution. Japan; Corea; China; Siberia.

Hypocala subsatura.

Hypocala subsatura Guen. Noct. III. p. 75 (1852); Leech, Trans. Ent. Soc. 1900, p. 545; Warren, Seitz, Macrolep. III. p. 382, pl. 69 F.

Hypocala aspersa Butl. P. Z. S. Lond. 1883. p. 164.

Hypocala subsatura var. *limbata* Butl. Ill. Het. VII. p. 76, pl. 131. f. 13 (1899).

A male of the typical form taken by me at Miyanoura, Yakushima, July 12, 1918.

Local distribution.   Honshiu ; Kiushiu.

General distribution.   Japan ; China ; India.

Oræsia emarginata.

Noctua emarginata Fabr. Ent. Syst. III. 2, p. 82 ; Hampsn. Moths Ind. II. p. 564 ; Leech, Trans. Ent. Soc. 1900, p. 578 ; Warren, Seitz, Macrolep. p. 383, pl. 69 h.

Oræsia allicions Wlk. Cat. XII, p. 945 (1857).

Oræsia tentans Wlk. Cat. XII. p. 945 (1857).

Oræsia metallescens Guen. Noct. II. p. 364 (1852).

A female taken by me in Yakushima, July 11, 1918.

Local distribution.   Honshiu ; Kiushiu.

General distribution.   Japan ; Corea ; China ; India.

Oræsia excavata.

Calp. excavata Butl. A. M. N. H. (5) I. p. 202 (1878); Ill. Het. B. M. II. p. 35, pl. 32. f. 1 (1878); Leech, Trans. Ent. Soc. 1900, p. 579 ; Warren, Seitz, Macrolep. III. p 384, pl. 69 h.

A male taken by me at Nishinoomote, Tanegashima, July 23, 1918.

Local distribution.   Honshiu ; Kiushiu.

General distribution.   Japan ; Corea ; China.

Plusiodonta cœlonota.

Plusiodonta cœlnota Koll. Hüg. Kasch. IV. p. 482 ; Hmpsn. Moths Ind. II. g. 578 ; Leech, Trans. Ent. Soc. 1900, p. 590 ; Warren, Seitz, Macrolep. III. p. 384, pl. 70 a.

Plusiodonta chalsytoides Guen. Noct. II. p. 360.

Dera conducens Wlk. Cat. XII. p. 963.

Plusia agens Feld. Reis. Nov. pl. 110, f. 32 (1874).

A male taken by me at Nishinoomote, Tanegashima, July 27, 1918.

Local distribution.   Honshiu ; Kiushiu.

General distribution.   Japan ; Loochoo ; Corea ; China ; India ; Java.

Subfam. PCTYPOGONINÆ.

Pseudaglossa pryeri.

Homima pryeri Butl. Ill. Het. B. M. III. p. 63. pl. 56. f. 11 (1879 ; Leech, Trans. Ent. Soc. 1900, p. 616 ; Warren. Seitz, Macrolep. III. p. 414. pl. 74 f.

A female taken by me at Miyanoura, Yakushima. July 12. 1918.

Local distribution.　Honshiu : Kiushiu.

Habitat.　Japan.

Edessena hamada.

Ramades hamada Feld. Reis. Nov. pl. 119. f. 23 (1874) ; Leech. Trans. Ent. Soc. 1900, p. 628 ; Warren, Seitz, Macrolep. III. p. 414, pl. 72 a.

A female taken by me at Nishinoomote, Tanegashima, July 23. 1918.

Local distribution.　Honshiu ; Kiushiu.

General distribution.　Japan ; China.

Dichromia trigonalis.

Dichromia trigonalis Guen. Delt. et Pyr. p. 19 (1854) ; Hmpsn. Moths Ind. III. p. 73 (1895) ; Leech, Trans. Ent. Soc. 1900, p. 648 ; Warren, Seitz, Macrolep. III. p. 427, pl. 72 h, i.

Dichromia sextalis Wlk. Cat. XVI· p. 15 (1858).

Common in both Yakushima and Tanegashima.

Local distribution.　Honshiu ; Kiushiu.

General distribution.　Japan ; Corea ; Formosa ; China ; India.

Fam. Liparidæ.

Porthesia pulverea.

Artaxa pulverea Leech. P. Z. S. 1888, p. 623. pl. 31. f. 5 ; Fritze, Faun. Liu-Kiu. Ins. p. 65 ; Trans. Ent. Soc. 1899, p. 140 ; Straud, Seitz, Macrolep. II. p. 136, pl. 21 F.

Took a male (expanse 20 mm. at Nishinoomote, Tanegashima, July 25, and a female (expanse 36 mm.) on Mt. Miyanoura, Yakushima, July 16, 1918.

In my collection there are two males and a female taken at Nachi, Kii (Honshiu) and Komori, Yamato (Honshiu).

In the hindwings the vein 5 is absent.

Local distribution. Honshiu; Kiushiu.

General distribution. Japan; Loochoo; Corea.

Porthetria dispar.

(Pl. III, fig. 3.)

Bombyx dispar Linn. Syst. Nat. 10 ed. p. 501 (1758); Kirby, Cat. Het. p. 475; Leech, Trans. Ent. Soc. 1899, p. 130; Strand, Seitz, Macrolep. II. p. 127, pl. 10 d.

Bombyx disparina Müll. Faun. Siles. III. pl. 3. f. 1 (1802).

Lymantria fasciata Rebel, Berge's Schmett. p. 118.

Lyparis dispar var. *bordigalensis vel disparoides* Mab. Gasch. Bull. et Ann. Soc. Ent. Fr. (5) VI. pp. IX. 521 (1876).

Ocneria dispar ab. *semiobscura, erebus* Mieg. Le Nat. VIII. p. 237 (1876).

Lymantria dispar insignata, amplifera, unifascia, submarginalis Schultz. Ent. Zeitschr. Stutt. XXIV. pp. 35–36.

Liparis dispar var. *japonica* Motsch. Etud. Ent. 1860, p. 31.

Lymantria sinica Moore, P. Z. S. 1879, p. 403.

Lymantria fumida Butl. A. M. N. H. (4) XX. p. 402; Ill. Het. B. M. II. pl. 24. f. 4 ♀; Trans. Ent. Soc. 1881, p. 11 ♂.

Porthesia umbrosa Butl. Trans. Ent. Soc. 1881, p. 10.

Lymantria dispar ab. *wladiwostokensis* Strand, Seitz. Macrolep. II. p. 127. pl. 20 C.

A male with abnormally white hindwings taken by me at Kusukawa, Yakushima, July 21, 1918.

Local distribution. Hokkaido; Honshiu; Shikoku; Kiushiu.

General distribution. Palaearctic and Arctic regions; North America.

Porthetria nobunaga.

Lymantria nobunaga Nagano, Nawa, Insect World. XVI. p. 262, pl. 14. figs.
  1, 2 (1912).

  A male taken by me in Yakushima, July 13, 1918.

  Local distribution.   Honshiu (Kii, Mino); Kiushiu (Yakushima).

  Habitat. Japan.

Fam. **Callimorphidæ.**

Nyctemera mundipicta.

Nyctemera mundipicta Wlk. Journ. Linn. Soc. Lond. Zool. III. p. 184 (1859);
  Kirby, Cat. Het. I. p. 421.

  MIYAKE stated he has seen an example at Miyanoura, Yakushima, August
1909.

  Hitherto unrecorded from Japan.

  Local distriction.   Kiushiu (Yakushima).

  General distribution.   Japan ; Java ; Malay.

Nyctemera plagifera.

Nyctemera plagifera Wlk. Cat. II. p. 400 ; Butl. Ill. Het. B. M. V. p. 45, pl.
  88. f. 3 ; Hmpsn. Moths Ind. II, p. 47 ; Fritze, Faun. Liu-Kiu-Ins. p.
  65 ; Leech, Trans. Ent. Soc. 1899, p. 169 ; Seitz, Seitz, Macrolep II. p
  103, pl. 18 h.

  A female taken by HABUTSU in Yakushima, August 1910.

  Local distribution.   Kiushiu.

  General distribution.   Japan ; Loochoo ; Formosa ; China ; India.

Nyctemera cenis.

Geometra cenis Cram. Pap. Exot. II. pl. 147. f. E (1779 ?); Kirby, Cat. Het.
  I. p. 423 ; Hmpsn. Moths Ind. II. p. 48.

Nyctemera interlecta Wlk. Cat. II p. 400 ; Butl. Ill. Het. B. M. V. p. 45, pl.
  88. f. 2.

  A female taken by HABUTSU, August 1910, and also by me, July 13,

1918, in Yakushima. The species are very common at Jurokuban, Tanega-shima, in June.

Hitherto unrecorded from Japan.

Local distribution. Kiushiu (Yakushima, Tanegashima).

General distribution. Japan; Loochoo; Formosa; Yunnan; India.

Fam. **Sphingidæ**.

Subfam. SPHINGINÆ.

Herse convolvuli.

Sphinx convolvuli Linn. Syst. Nat. 10 ed. p. 490 (1758); Hmpsn. Moths Ind.
    I. p. 103; Fritze, Faun. Liu-Kiu-Ins. p. 63; Leech, Trans. Ent. Soc.
    1898, p. 286; Roths. et Jord. Rev. Shin. p. 11; ford. Seitz, Macrolep.
II, p. 233, pl. 36 a.

Sphinx abadonna Fabr. Ent. Syst. Suppl. p. 435 (1798).

Sphinx rosefasciata Koch. ind. Austr. Lep. Faun. p. 54 (1865).

Sphinx pseudoconvolvuli Schaufuss, Nung. Otios. p. 15 (1870).

Sphinx distans Butl. Lep. N. Zeal. p. 4, pl. 2. f. 11 (1874).

Protoparce orientalis Butl. Trans. Zool. Soc. Lond. IX. p. 609 (1877).

Sphinx convolvuli var. *batatæ* Christ. Mitth. Schw. Ent. Ges. VI. p. 346 (1884).

Sphinx convolvuli var. *aliena* Neuburger, Ill. Zeitschr. Ent. IV. p. 297 (1899).

Sphinx convolvuli var. *nigricans* Cannaviello, Bull. Soc. Ent. Ital. XXXII. p.
    295 (1900).

*Agrius convolvuli var. ichagensis, tahitiensis, minor, major, grisea, unicolor,
    intermedia, fuscosignate, virgata, variegata, suffusa, obscura* Tutt. Brit. Lep.
    IV. (1904).

Five males taken by MIYAKE in Yakushima, August 1909.

Local distribution. Hokkaido; Honshiu; Shikoku; Kiushiu.

General distribution. Japan; Loochoo; Formosa?; Borneo; Java; Celebes;
India: Europe.

Subfam. SESIANÆ.

Cephonodes xanthus.

Cephonodes xanthus Roths. et Jord. Rev. Sphin. p. 465, pl. 5. f. 17 ♀ (1903).

Two males taken by HABUTSU in Tanegashima. August 1910 and I have also received a female from the same locality.

Local distribution. Kiushiu (Tanegashima).

General distribution. Japan; Loochoo.

Subfam. MACROGLOSSINÆ.

Gurelca masuriensis.

Lophura masuriensis Butl. P. Z. S. 1875, p. 244, pl. 36, f. 3; Hmpsn. Moths Ind. I. p. 110; Leech, Trans. Ent. Soc. 1898, p. 291; Roths. et Jord Rev. Shin. p. 589; Jord. Seitz, Macrolep. II. p. 251.

Lophura himachala Butl. P. Z. S. 1875, p. 621.

Lophura crebina Butl. P. Z. S. 1875, p. 621.

Lophura sanguica Butl. P. Z. S. 1875, p. 621; Jord. Seitz, Macrolep. II. p. 251, pl. 40 g.

A male taken by HABUTSU in Tanegashima, August 1910.

Local distribution, Honshiu; Kiushiu.

General distribution. Japan; Corea; Formorsa; China; India.

Gurelca hyas.

Lophura hyas Wlk. Cat. Viii. p. 107 (1856); Hmpsn. Moths Ind. I. p. 110; Leech, Trans. Ent. Soc. 1898, p. 291; Roths. et Jord. Rev. Sphin. p. 588; Jord. Seitz, Macrolep. II. p. 251, pl. 40 g.

Macroglossum geometricum Moore, Cat Lep. Ins. Mus. E. I. C. I, p. 265 (1857).

Perigonia macroglossoides Wlk. Cat. XXXV. p. 1851 (1866).

A male specimen.

Local distribution. Honshiu; Kiushiu.

General distribution. Japan; Formosa; China; Java; India.

Macroglossum pyrrhosticta.

Macroglossa pyrrhosticta Butl. P. Z. S. 1875, p. 242, pl 36. f. 8; Fritze.
 Faun. Liu-Kiu-Ins. p. 62; Leech, Trans. Ent. Soc. 1898, p. 293; Roths.
 et Jord. Rev. Sphin. p. 641, pl. 3. f. 12; Jord. Seitz, Macrolep. II. p.
 253, pl. 40 f.

Macroglossa gilia Boisduval, Spec. Gen. Lep. Het. I. p. 341 (1875)

Macroglossa catapyrrha Butl. P. Z. S. 1875, p. 243, pl. 36. f. 6.

Miyake records this species in his own list.

Local distribution. Honshiu: Kiushiu.

General distribution. Japan; Loochoo; Lombok; India.

Subfam. CHÆRIANÆ.

Theretra oldenlandiæ.

Sphinx oldenlandiæ Fabr. Syst. Ent. p. 542 (1775); Moore, Lep. Ceyl. II. p.
 17, pl. 85. f. 85; Hmpsn. Moths Ind. I. p. 87; Leech, Trans. Ent. Soc.
 1898, p. 283; Roths. et Jord. Rev. Sphin. p, 781; Jord. Seitz. Macrolep.
 II. p. 259, pl. 42 b.

Sphinx dranens Cram. Pap. Exot. II. pl. 132. f. F (1777).

Sphinx argentata Stephens, Ill. Brit. Ent. Haust. I. p. 130 (1828).

Chærocampa puellaris Butl. P. Z. S. 1875, p. 623.

Chærocampa firmata Wlk. Cat. VIII. p. 148 (1856).

Chærocampa argentata Butl. P.Z. S. 1875, p. 8, pl. 2. f. 3.

A male taken by Miyake.

Local distribution. Hokkaido: Honshiu; Shikoku: Kiushiu.

General distribution. Japan; Corea; China; Philippines; Java; India;
New Guinea; Australia.

Theretra silhetensis.

Chærocampa silhetensis Wlk. Cat. VIII. p. 143 (1858); Butl. Ill. Het. B. M.
 V. pl. 79, f. 6; Leech, Trans. Ent. Soc. 1898, p. 284.

Sphinx pinastrina Martyn, ined. (1797).

Chærocampa bisecta Moore, Cat. Lep. Mus. E. I. C. I. p. 278 (1857).

Chærocampa intersecta Butl. P. Z. S. 1875, p. 623.

　　Two males.

　　Local distribution.　Kiushiu.

　　General distribution.　Japan; Loochoo; Formosa; China; Philippines;
Borneo; Java; India.

Fam. Ceruridæ.

Ramesa straminea.

Ceira straminea Moore, A. M. N. H. (4) XX. p. 91 (1877); Leech, Trans. Ent.
　　Soc. 1898, p. 301; Grünberg, Seitz, Macrolep. II. p. 316, pl. 47 g.　Maru-
　　mo, Journ. Coll. Agr. Imp. Univ. Tokyo. VI. p. 343.
　　A male taken by me at Noma, Tanegashima, June 13, 1919.
　　Local distribution.　Honshiu; Kiushiu.
　　General distribution.　Japan; Corea; China.

Fam. Geometridæ.

Subfam URAPTERYGINÆ.

Tristrophis subpunctaria.

Urapteryx subpunctaria Leech, Entom. XXIV. Suppl. p. 42 (1891); A. M. N. H.
　　(6) XIX. p. 192, pl. 6. f. 2; Prout, Seitz, Macrolep. IV. p. 336, pl. 17 f.
　　A male taken by me on Mt. Miyanoura, Yakushima, July 15, 1918.
　　Local distribution.　Honshiu; Kiushiu.
　　Habitat.　Japan.

Thinopteryx crocoptera.

Urapteryx crocoptera Koll. Hüg. Kasch. IV. p. 483 (1848); Hmpsn. Moths
　　Ind. III. p. 148; Leech, A. M. N. H. (6) XIX. p. 193; Prout, Seitz, Mac-
　　rolep. IV. p. 336, pl. 17 f.

Thinopteryx striolata Butl. Journ. Linn. Soc. Zool. XVIII. p. 202 (1883).
　　A male taken by me at Kosugitani, Yakushima, July 19, 1918.

Local distribution. Honshiu; Kinshiu.

General distribution. Japan; Corea; China; India.

Synegia esther.

Synegia esther Butl. Trans. Ent. Soc. 1881, p. 411; Leech, A. M. N. H. (6)
XIX. p. 204; Prout, Seitz, Macrolep. IV. p. 319.

A female taken by me in Yakushima, July 13, 1918.

Local distribution. Honshiu; Kinshiu.

General distribution. Japan; China.

Synegia hadassa.

Acisches hadassa Butl. A. M. N. H. (5) I. p. 409 (1878); Ill. Het. B. M. III.
p. 38, pl. 50. f. 8; Leech, A. M. N. H. (6) XIX. p. 204.

Synegia inconspicua Butl. Trans. Ent. Soc. 1881, p. 412.

Saturnata hadassa ab. *unicolor* Wileman, Trans. Ent. Soc. 1911, p. 299, pl.
31. f. 26.

Synegia hadassa suffusa Prout, Seitz, Macrolep. IV. p. 318.

Two males of the *inconspicua* form taken by me at Kosugitani, Yaku-
shima, July 14 and 15, 1918.

Local distribution. Hokkaido; Honshiu; Kinshiu.

General distribution. Japan; China.

Scionomia mendica.

Cidaria mendica Butl. A. M. N. H. (5) IV. p. 446 (1879); Leech, A. M. N. H.
(6) XIX. p. 226; Prout, Seitz, Macrolep. IV. p. 338.

A female taken by me in Yakushima, July 14, 1918.

Local distribution. Hokkaido; Honshiu; Kinshiu.

General distribution. Japan; China.

Zethenia rufescentaria.

Zethenia rufescentaria Motsch. Etud. Ent. p. 35 (1866); Leech, A. M. N. H. (6)
XIX. p. 223; Prout, Seitz, Macrolep. IV. p. 330, pl. 16 d, e.

Zethenia consociaria Christ. Bull. Mosc. 1880, p. 66.

A male taken by me at Kosugitani, Yakushima, July 14, 1918.

Local distribution.   Hokkaido; Honshiu; Kiushiu.

General distribution.   Japan; Corea; Siberia.

Heterolocha laminaria.

Urapteryx laminaria H.-Schäff. Syst. Schmett. Eur. VI. p. 71 (1843–1856).
Hyperythra(?) aristomaria Wlk. Cat. XX. p. 130 (1860).
Hyperythra niphonica Butl. Ill. Het. B. M. II. p. 46. pl. 35. f. 11 (1878).
Heterolocha laminaria bicolor Prout, Seitz. Macrolep. IV. p. 340.

A male and four females taken by me at Nishiroomote and Noma, Tanega-shima, July 26, 1918, and June 10 and 11, 1919.

Local distribution.   Hokkaido; Honshiu; Kiushiu.

General distribution.   Japan; Corea; China; Persia; Asia Minor.

Corymica specularia.

Caprilia specularia Moore, P. Z. S. 1867, p.649. pl. 33. f. 11; Hmpsn. Moths
    Ind. III. p. 186; Leech. A. M. N. H. (6) XIX. p. 298; Prout, Seitz,
    Macrolep. IV. p. 339.
Thiopsyche pryeri Butl. A. M. N. H. (5) 1. p. 393; Ill. Het. B. M. III. p. 29.
    pl. 48. f. 2.
Corymica vitrigera Butl. Ill. Het. B. M. VII. p. 101. pl. 135. f. 14 (1889).
    A male taken by me in Yakushima, July 14, 1918.
    Local distribution.   Honshiu, Kiushiu.
    General distribution.   Japan; China; India.

Spilopera gracilis.

Endropia gracilis Butl. A. M. N. H. (5) IV. p. 371 (1879); Hmpsn. Moths.
    Ind. III. p. 190; Leech, A. M. N. H. (6) XIX. p. 309; Prout, Seitz,
    Macrolep. IV. p. 345. pl. 18. e.
    A female taken by me at Kosugitani, Yakushima, July 14, 1918.
    Local distribution.   Hokkaido; Honshiu; Kiushiu.
    General distribution.   Japan; Formosa; Corea; China; India.

Rhynchobapta flaviceps.

Nodapta flaviceps Butl. Trans. Ent. Soc. 1881, p. 419; Hmpsn. Moths Ind. III. p. 195; Leech, A. M. N. H. (6) XIX. p. 303; Prout, Seitz, Macrolep. IV. p. 315, pl. 18 e.

A male taken by me at Nishinoomote, Tanegashima, July 26, 1918.

Local distribution. Honshiu; Shikoku; Kiushiu.

General distribution. Japan; China; India.

Macaria pluviata.

Macaria pluviata F.; Prout, Seitz, Macrolep. IV. p. 343.

Macaria sujfata Guen. Phal. II. p. 88, pl. 17. f. 8. (1857).

Macaria holosata Wlk. Cat. XXIII. p. 931 (1861); Butl. Ill. Het. B. M. III. pl. 52. f. 1.

Macaria sinicaria Wlk. Cat. XXVI. p. 1650 (1862).

Macaria breviusculata Wlk. Cat. XXVI. p. 1650 (1862).

Macaria proditaria Brem. Lep. Ost-Sib. p. 81, pl. 7. f. 7. (1864).

Macaria maligna Butl. A. M. N. H. (5) 1. p. 405 (1878); Ill, Het. B. M. III. p. 45, pl. 52. f. 3.

Gonodela horridaria Moore, Lep. Atk. p. 262 (1888).

Common in Tanegashima in June and July.

Local distribution. Honshiu; Kiushiu.

General distribution. Japan; Corea; Siberia; China; India.

Tephrina semilutata.

Eubolia semilutata Led. Sib. Schmett. p. 29, pl. 6. f. 3 (1853); Meyrick, Trans. Ent. Soc. 1892, p. 103; Leech, A. M. N. H. (6) XIX. p. 311; Prout, Seitz, Macrolep. IV. p. 406.

Chaerodes dictynna Butl. Ill. Het. B. M. II. p. 45, pl. 35. f. 7 (1878).

A male and three females taken by HABUTSU in Yakushima, and Tanegashima, August and September, 1910.

Local distribution. Hokkaido; Honshiu; Kiushiu.

General distribution. Japan; Corea; China; Siberia.

Arichanna jaguararia.

Arichanna jaguararia Guen. Phal. II. p. 198 (1857); Leech, A. M. N. H. (6)
XIX. p. 439; Prout, Seitz, Macrolep. IV. p. 305, pl. 14 c.

Very common at Kosugitani, Yakushima, in July.

Local distribution.   Honshiu; Kiushiu.

General distribution.   Japan; China.

Abraxas miranda.

Abraxas miranda Butl. A. M. N. H. (5) I. p. 441 (1878); Ill. Het. B. M. III.
p. 48, pl. 52. f. 12; Prout, Seitz, Macrolep. IV. p. 311. pl 15 b.

Abraxas latifasciata Warr. Novit. Zool. I. p. 419 (1894).

Abraxas suffusa Warren, Novit. Zool. I. p. 417 (1894).

Abraxas sylvata ab. *continuata* Warren, Novit. Zool. X. p. 269 (1903).

A female taken by me on Mt. Miyanoura, July 18, 1918.

Local distribution.   Hokkaido; Honshiu; Shikoku; Kiushiu.

General distribution.   Japan; Corea; Siberia; India; Europe.

Subfam. PSYCHOPHORINÆ.

Asthena erectaria.

Cidaria erectaria Leech, A. M. N. H. (6) XIX. p. 651 (1897); Prout. Seitz.
Macrolep. IV. p. 273, pl. 7 g.

A female taken by me at Kosugitani, Yakushima, July 14, 1918.

Local distribution.   Hokkaido; Honshiu (Yamato); Kiushiu (Yakushima).

Habitat.   Japan.

Cidaria saturata.

Larentia saturata Guen. Phal. II. p. 269 (1857); Hmpsn. Moths Ind. III. p.
362; Leech, A. M. N. H. (6) XIX. p. 652; Prout. Seitz, Macrolep. IV. p.
227, pl. 7 f.

Larentia exliturata Wlk. Cat. XXIV. p. 1195 (1862).

Coremia livida Butl. A. M. N. H. (5) I. 449; Ill. Het. B. M. III. p. 56, pl.
55. f. 2.

Larentia inamœna Butl. A. M. N. H. (5) IV. p. 444 (1879).

A female of *licida* form taken by me at Kosugitani, Yakushima. July 18, 1918.

Local distribution.   Honshiu ; Kiushiu.

General distribution   Japan, China : India : S. Africa.

Photoscotosia atrostrigata.

Scotosia atrostrigata Brem. Lep. Ost-Sib. p. 87, pl. 7. f. 16 (1864); Leech, A. M. N. H. (6) XIX. p. 675 ; Prout. Seitz, Macrolep, IV. p. 202, pl. 5 h.
Scotosia lucicolens Butl. Ill. Het. B. M. II. p. 54. pl. 37. f. 10 (1878).

A female taken by me at Kosugitani, Yakushima. July 14. 1918.

Local distribution.   Honshiu ; Kiushiu.

General distribusion.   Japan ; China ; Siberia ; Formosa.

Subfam. SCOPULINÆ.

Scopula steganioides.

Acidalia steganioides But. Ill. Het. B. M. II. p. 51, pl. 37. f. 8 (1878); Leech, A. M. N. H. (6) XX. p. 103 ; Prout, Seitz, Macrolep. IV. p. 54, pl. 4 m.
Acidalia steganioides ab. *micolor* Prout, Seitz, Macrolep. IV. p. 55 (1913).

A female taken by me at Miyanoura, Yakushima, July 12, 1918, and a male by Miyake. August 1909.

Local distribution.   Honshiu, Kiushiu.

General distribution.   Japan ; Corea.

Scopula lactea.

Lycauges lactea Butl. A. M. N. H. (5) IV. p. 373 (1879); Prout, Seitz, Macrolep. IV. p. 54, pl. 3 g.
Acidalia emissaria Hmpsn. (part) Moths Ind. III. p. 435 (1895), nec Wlk.

A male and a female taken by me at Noma, Tanegashima, June 10 and 11, 1919.

Local distribution.   Honshiu, Kiushiu.

General distribution.   Japan ; China.

Scopula ignobilis.

Craspedia ignobilis Warren, Novit. Zool. VII. p. 22 (1901); Wileman, Trans.
    Ent. Soc. 1911, p. 334; Prout, Seitz, Macrolep. IV. p. 60, pl. 4 m.
Acidalia ignobilis subsp. *humilis* Prout, Seitz, Macrolep. IV. p. 61. (1913).

A male and a female taken by me at Kosugitani, Yakushima, July 14,
1918.

Local distribution.   Honshiu; Kiushiu.

General distribution.   Japan; China.

Scopula satsumaria.

Acidalia satsumaria Leech, A. M. N. H. (6) XX. p. 91 (1897); Prout, Seitz,
    Macrolep. IV. p. 78. pl. 5 e.

A male taken by me at Kusukawa, Yakushima, July 20, 1918.   In the
specimen the terminal black dots of both wings are almost entirely absent.

Local distribution.   Kiushiu.

Habitat.   Japan.

Scopula hanna.

Acidalia hanna Butl. A. M. N. H. (5) I. p. 401 (1878); Ill. Het. B. M. III. p.
    40, pl. 50. f. 11; Leech, A. M. N. H. (6) XX. p. 101; Prout, Seitz,
    Macrolep. IV. p. 75, pl. 3 m.

A male specimen.

Local distribution.   Honshiu; Kiushiu.

General distribution.   Japan; Corea.

Scopula apicipunctata.

Acidalia apicipunctata Christ. Bull. Mosc. II. p. 54 (1880); Staud. Cat. pal.
    p. 275; Prout, Seitz, Macrolep. IV. p. 70, pl. 5 b.
Acidalia arenaria Leech, A. M. N. H. (6) XX. p. 95 (1897).

A female taken by me at Miyanoura, Yakushima, July 12, 1918.

Local distribution.   Kiushiu; Honshiu.

General distribution.   Japan   Corea; China; Siberia.

Scopula coniaria.

Acidalia pulveraria Leech, A. M. N. H. (6) XX. p. 98 (1897).

Acidalia coniaria Prout, Seitz, Macrolep. IV. p. 72, pl. 3 m (1913)

A male and a female taken by me at Miyanoura, Yakushima and Nishi-noomote, Tanegashima, July 12 and 27, 1918.

Local distribution. Honshiu; Kiushiu.

Habitat. Japan.

Scopula plumbearia.

Acidalia plumbearia Leech, Entom. Suppl. p. 55 (May 1891); A. M. N. H.
   (6) XX. p. 100; Prout, Seitz, Macrolep. IV. p. 73, pl. 5 f.

A male taken by me at Nishinoomote, Tanegashima, July 26, 1918.

Local distribution. Kiushiu.

Habitat. Japan.

Timandra amata.

Geometra amata Linn. Syst. Nat. 10 ed. p. 524 (1758); Prout, Seitz, Macro-
   lep. IV. p. 47, pl. 5 f.

Calothysanis amataria Hübn. Verz. Schmett. p. 31.

Timandra amataria Dup. Lep. VII. pl. 148. f. 3; Hmpsn. Moths Ind. III.
   p. 458; Leech, A. M. N. H. (6) XIX. p. 109.

Timandra comptaria Wlk. Cat. XXVI. p. 1615; Butl. Ill. Het. B. M. III.
   pl. 61. f. 2.

Timandra amata ab. *suffumata* Prout. Seitz, Macrolep. IV. p. 43 (1913).

Timandra amata ab. *bipartita* Prout, Seitz, Macrolep. IV. p. 48 (1913).

A female of the *comptaria* form taken by me at Miyanoura, Yakushima,
July 12, 1918.

Local distribution. Hokkaido; Honshiu; Shikoku: Kiushiu.

General distribution. Japan; Siberia; China; India; Europe.

Subfam. GEOMETRINÆ.

Chloromachia infracta.

Thalassodes infracta Wileman, Trans. Ent. Soc. 1911, p. 342, pl. 30. f. 16, ♀ ;
    Prout, Seitz, Macrelop. IV. p. 18.

♀. Palpi with the third joint long. Forewings with a larger brown-tinged white patch at anal angle. Hindwings without green tinge on the broad brown-tinged white terminal area. Expanse 32 mm.

A female taken by me at Kusukawa, Yakushima, July 20, 1918.

Local distribution. Honshiu ; Kiushiu (Yakushima).

Habitat. Japan.

Subfam. ALETINÆ.

Doratoptera (?) *virescens.*

(Pl. III. fig. 4)

♀. Body rather robust. Head and thorax hairy. Palpi porrect. clothed with long hair, and not reaching beyond frons, proboscis well developed. Antennæ minutely ciliated ; vertex of head with a high erect crest of hair. Legs rather stout, hind tibiæ with two pairs of spurs. Forewings with the apex acute but not so extremely produced as in *D. nicevillei* Hmpsn.: anal angle rounded off ; venation as in *D. nicevillei*. Hindwings with the apex arched and pointed at end of vein 7 ; venation as in *D. nicevillei.*

Palpi, frons, and the face of crest of vertex brownish orange. Thorax and forewings greenish yellow, the former streaked with orange at middle. Wings satiny texture. Hindwings white faintly tinger with yellowish. Fore legs brownish fulvous with the terminal segments of tarsi white. Abdomen whitish.

Expanse 54 mm.

Received two females from Miyeda, taken at Kosugitani. Yakushima, June 1918. I also met with a female in Tanegashima.

Fam. **Uraniadæ.**

Subfam. EPIPLEMINÆ.

Epiplema moza.

Erosia moza Butl. A. M. N. H. (5) 1. p. 402 (1868); Ill. Het. B. M. III. p. 42, pl. 51, f. 7; Leech, A. M. N. H. (6) XIX. p. 184.

A male taken by me at Nishinoomote, Tanegashima, July 23, 1918.

Local distribution. Honshiu: Kiushiu.

General distribution. Japan: India.

Epiplema cretacea.

Erosia cretacea Butl. Trans. Ent. Soc. 1881, p. 414; Leech. A. M. N. H. (6) XIX. p. 185.

Two females taken by me at Noma, Tanegashima, June 15 and 16, 1919.

Local distribution. Honshiu: Kiushiu.

Habitat. Japan.

Fam. **Heterogeneidæ.**

Miresa inornata.

Miresa inornata Wlk. Cat. V. p. 1125 (1855; Butl. Cist. Ent. III. p. 120 (1885); Hmpsn. Moths Ind. I. p. 386; Leech, Trans. Ent. Soc. 1899, p. 104; Seitz, Seitz, Macrolep. II. p. 344.

Two males and a female taken by me at Kosugitani, Yakushima, July 14, 1918.

Local distribution. Hokkaido; Honshiu; Kiushiu.

General distribution. Japan: China; India; Siberia.

Microleon longipalpis.

Microleon longipalpis Butl. Cist. Ent. III. p. 121 (1885); Leech, Trans. Ent. Soc. 1899, p. 107; Seitz. Seitz, Macrolep. II. p. 341, pl. 50 a.

A male taken by me at Kosugitani, Yakushima, July 15, 1918.

Local distribution. Honshiu; Kiushiu.

General distribution. Japan; Corea.

Fam. **Danaidæ**.

Subfam. EUPLŒINÆ.

Euplœa tytia.

Euplœa tytia Gray, Lep. Ins, Nepal. p. 2, pl. 9. f. 2 (1833–1846); Moore,
Lep. Ind. I. p. 61, pl. 15 f. 1, 1a–1e; Pryer, Rhop. Nihon. p. 29, pl.
8. f. 9; Leech, Butl. Chin. Jap. Cor. I. p. 1; Fritze, Faun. Liu-Kin-Ins.
p. 41; Miyake, Ann. Zool. Jap. VI. p. 64; Seitz, Seitz, Macrolep. I. p.
77, pl. 28 e.

Danais sita Koll. Hüg. Kasch. IV. p. 424, pl. 6 ,1844).

Caduga niphonica Moore, P. Z. S. 1883, p. 249.

Caduga loochooana Moore, P. Z. S. 1883, p. 250.

The *niphonica* form was found commonly on the summit of Mt. Miyano-
ura, Yakushima, in July 1918.

Local distribution. Hokkaido; Honshiu; Shikoku. Kiushiu.

General distribution. Japan; Loochoo; Formosa; China; Malay; India.

Subfam. MANIOLINÆ.

Ypthima argus.

Ypthima argus Butl. Journ. Linn. Soc. Zool. IX. p. 56 (1866); Elw. et Edw.
Trans. Ent. Soc. 1893, p. 35, pl. 2. f. 28; Leech, Butl. Chin. Jap. Cor.
II. p. 649; Fruhst. Seitz, Macrolep. IX. p. 290; Niré, Dobutsu-zas.
1917, Suppl. p. 13.

Ypthima evanescens Butl. A. M. N. H. (5) VII. p. 134. (1881).

Ypthima bœldus Pryer (nec Fabr.), Rhop. Nihon. p. 30, pl. 9. f. 3 (1889); Seitz,
Seitz, Macrolep. I. p. 91.

Ypthima philomera Leech (nec Johans.), Butl. Chin. Jap. Cor. I. p. 90 (1892).
Not uncommon. They are all *argus* form.

Local distribution. Hokkaido; Honshiu; Shikoku; Kiushiu.

General distribution. Japan; Corea; Siberia; China.

Neope goschkevitschii.

(Pl. III. fig. 5.)

Lasiommata goschkevitschii Mén. Cat. Mus. Peterz II. p. 121, pl. 10. f. 4
    (1855); Leech, Butl. Chin. Jap. Cor. I. p. 52; Seitz, Seitz, Macrolep. I.
    p. 90, pl. 32 e; Wileman, Philip. Journ. Scien. IX. p. 258, pl. 2. figs.
    7–11, larva; Niré, Dobutsu-zas. 1917, Suppl. p. 24.

Lasiommata goschkevitschii Feld. (Nec Mén.), Wien. Ent. Mon. VI. p. 28
    (1862); Pryer, Rhop. Nihon. p. 32, pl. 9. f. 14.

Neope goschkevitschii Matsumura (nec Mén.), Cat. Ins. Jap. I. p. 14 (1905).

Neope japonica Butl. A. M. N. H. (5) VII. p. 133 (1887).

    On the summit of Mt. Miyanoura I met with a good deal of the dark
form of this species, which were at first considered as a distinct species. The
yellow colour on the underside of the wings, especially of the hindwings, is
entirely replaced by white and fuscous.

    Local distribution. Hokkaido; Honshiu; Shikoku; Kiushiu.

    Habitat. Japan.

Melanitis phedisma.

Papilio phedisma Cram. Pap. Exot. IV. pl. 292; Fruhst. Seitz, Macrolep. IX
    p. 363.

Melanitis bela Moore, Cat. Lep. Mus. E.I.C. I. p. 223 (1857).

Melanitis varaha Moore, Cat. Lep. Mus. E. I. C. I. p. 224 (1857).

Melanitis gokala Moore, Cat. Lep. Mus. E. I. C. I. p. 224 (1857).

Melanitis aswa Moore, P. Z S. 1865, p. 769.

Melanitis tambra Moore, Lep. Ceyl. I. p. 15, pl. 9. figs. 2, 2a–2c, ♂♀, larva
    and pupa (1880).

Melanitis aculeata Hmpsn. J, A. S. B. 1888, p. 351.

Melanitis ampa Swinhoe, A. M N. H. (6) V. p. 353 (1890).

Melanitis lethami Nicév. P. Z. S. 1887, p. 451.

Lethe sicelis Miyaj. (part). Dobutsu-zas. 1899, p. 330, p. 330, pl. 17. f. 2.

Melanitis aswa var. *tristis* Miyake (nec Feld), Ann. Zool. Jap. 1907, p. 67.

Melanitis muskata, patra, autumnalis, ganapati, aswina, polishana, sumati, linga.
    Fruhst. Ent. Zeit. Stuttg. 1908, pp. 80–82.

Melanitis galkissa, engonica, falcinotaia, nyaga, nucara, Fruhst. Seitz, Macrolep.
IX. p. 364.

Three males and a female taken by MIYAKE. I also met with this
species in Tanegashima.

Local distribution. Honshiu ; Shikoku ; Kiushiu.

General distribution. Japan ; Loochoo ; Formosa ; Corea ; India.

Melanitis leda.

Nymphalis leda Linn. Syst. Nat. 12 ed. p. 773 (1767 ; Pryer, Rhop. Nihon.
    p. 30, pl. 8, f. 8 ; Leech, Butt. Chin. Jap. Cor. I. p. 106, pl. 12. figs.
    2, 5 ; Fritze, Faun. Liu-Kiu-Ins. p. 51 ; Seitz, Macrolep. I. p. 89, pl. 32 e.
Melanitis determinata Butl. Ent. Mon. Mag. XXI. p. 246 (1855).
Papilio ismene Cram. Pap. Exot. I. pl. 26. figs. A. S. (1775).
Papilio mycena Cram. Pap. Exot. IV. pl. 291. fig. F (1782).

Miyake took a female in Tanegashima, August 1909. Recorded also by
Iwata.

Local distribution. Honshiu ; Shikoku ; Kiushiu.

General distribution. Japan ; Formosa ; Corea ; India ; Africa.

Mycalesis gotama.

Mycalesis gotama Moore, Cat. Lep. Mus. E. I. C. I. p. 232. (1857) ; Pryer
    Rhop. Nihon. p. 30, pl. 9. f. 1 ; Leech, Butl. Chin. Jap. Cor. I. p. 14,
    pl. 2. f. 5 ; Seitz, Seitz, Macrolep. I. p. 81, pl. 29 c ; Wileman, Philip.
    Journ. Scien. IX. p. 264, pl. 3. figs. 8–16, larva.
Mycalesis borealis Feld. Reise Nov. Lep. p. 500 (1867).
Mycalesis madjicosa Butl. Cat. Satyr. B. M. p. 137, pl. 3. f. 10 (1868).
Mycalesis perdiccas Fritze (nec Hew.), Faun. Liu-Kiu-Ins. p. 52 (1892).
Mycalesis fulginia seriphus Fruhst. Seitz, Macrolep. IX. p. 348 (1911).

4 males and a female of the typical form.

Local distribution. Honshiu ; Shikoku ; Kiushiu.

General distribution. Japan ; Loochoo ; Corea ; China.

Subfam. DANAINÆ.

Dichorragia nesimachus.

Adolias nesimachus Boisl. Cuv. Règne Anim. Ins. II. pl. 139. f. 1 (1836) ;
Pryer, Rhop. Nihon. p. 22, pl. 5. f. 10 ; Leech, Butl. Chin. Jap. Cor. I.
p. 132 ; Fritze, Faun. Liu-Kiu-Ins. p. 48 ; Miyajima, Nihon-chor. p. 138
pl. 14. f. 8 ; Stichel, Seitz, Macrolep. I. p. 168, pl. 60 b.

Dichoragia nesseus nesiotes, jormosanus, pisistratus, pelurius, harpalyeus, pe'sand-
rus, *mamus,* etc. Fruhst. Seitz, Macrolep. IX. p. 696.

Two males taken by MIYAKE in Yakushima. I also met with it near
Nishinoomote, Tanegashima, July 1918.

Local distribution. Honshin ; Shikoku ; Kiushiu.

General distribution. Japan ; Loochoo ; Formosa ; China ; Malay ; India.

Cyrestis thyodamas.

Cyrestis thyodamas Boisl. Cuvier's Règ. Anim. Ins. II. pl. 138. f. 4 (1836) ;
Pryer, Rhop. p. 23, pl. 5. f. 14 ; Leech, Butl. Chin. Jap. Cor. I. p. 248 ;
Fritze, Faun. Liu-Kiu-Ins. p. 46 ; Miyajima, Nihon-Chor. p. 116, pl. 9.
f. 9 ; Stichel, Seitz, Macrolep. I. p. 173, pl. 61 e.

Amathusia ganesha Koll. Hüg. Kasch. IV. pt. 2 430, pl. 7. figs. 3, 4 (1848)

Cyrestis afgma, nobilior, chinensis Martin, Ins. XVI. pp. 86–87.

Cyrestis mabella, formosana Fruhst. Soc. Ent. XIII. p. 74 (1898).

Very common. All are of the *mabella* form.

Local distribution. Honshin ; Shikoku ; Kiushiu.

General distribution. Japan ; Loochoo ; Formosa ; China ; India.

Neptis hylas.

Nymphalis hylas Linn. Syst. Nat. 10 ed. p. 486 (1758); Stichel, Seitz, Macro-
lep. I. p. 175 ; Nire, Dobutsu-zas. 1918, Suppl. p.

Liminitis curynome Westwood, Donovan's Ins. Chin. 2nd ed. p. 66, pl, 38. f. 4
(1842).

Nepiis sangaica Moore, A. M. N. H. (4) XX. p. 47 (1877).

Neptis astola emodes, varmona Moore, P. Z. S. 1872, pp. 560-561.

Neptis hamarupa Moore, P. Z. S. 1874. p. 570.

Neptis andamana, nicoberica, disrupta Moore, P. Z. S. 1877, p. 586.

Neptis adara medama Moore. P. Z. S. 1878, p. 830.

Neptis swinhoei Butl. P. Z. S. 1883, p. 145, pl. 24. f. 9.

Neptis intermedia Pryer, Cist. Ent. II. p. 231, pl. 4. f. 1 (1877).

Neptis aceris Pryer (nec Leyechin), Rhop. Nihon. p. 24, pl. 16. f. 1 (1888);
Leech, Butt. Chin. Jap. Cor. I. p. 203; Miyajima, Nihon-chor. p. 127,
pl. 13. f. 1.

*Neptis yessoensis, passerculus, luculenta, acerides, hongkie, symada, laugeni,
batra* etc. Fruhst. Seitz, Macrolep. IX. p. 601.

5 males taken by MIYAKE in Tanegashima.

Local distribution. Hokkaido; Honshiu; Shikoku; Kiushiu.

General distribution. Japan; Loochoo; Corea; Formosa; China; India.

Junonia orithya.

Nymphalis orithya Linn. Syst. Nat. 10 ed. p. 473 (1758; Leech, Butt. Chin.
Jap. Cor. I. p. 279, pl. 25. figs. 8–10; Moore, Lep. Ceyl. I. p. 41, pl. 22.
figs. 1, 1a, 1b ♂ ♀, larva and pupa; Fritze, Faun. Liu-Kiu-Ins. p. 45;
Stichel, Seitz, Mrcrolep. I. p. 197, pl. 62 b, c; Niré, Dobutsu-zas. 1918,
Suppl. p. 15.

Junonia orithyia Doubleday (nec Linn.), Gen. Diurn. Lep. I. p. 209 (1849).

Junonia isocratia Hübn. Verz. p. 34 (1816).

Junonia orythia Wallace (nec Linn.), P. Z. S. 1866, p. 359.

Junonia orishya formosana Matsumura, Dobutsu-zas. 1909, p. 393.

A male of the typical form taken by me at Nishinoomote, Tanegashima,
July 2, 1918. Recorded also by IWATA.

Local distribution. Kiushiu (Kagoshima, Tanegashima, Yakushima).

General distribution. Japan; Loochoo; Formosa; China; Malay; India.

Junonia almana.

Nymphalis almana Linn. Syst. Nat. 10 ed. p. 472 (1758); Cram. Pap. Exot.
I. pl. 58. figs. F, G; Miyake, Ann. Zool. Jap. VI. p. 59; Stichel, Seitz,
Macrolep. I. p. 197, pl. 62 a; Niré, Dobutsu-zas. 1918, Suppl. p. 16.

Nymphalis asterie Linn. Syst. Nat. 10 ed. p. 472 (1758).

Several specimens of the *astræ* form taken by me in Tanegashima, July 1918. They frequent the flowers of *Phyllopterus littoralis* which grow in a great numbers on the coast of that island.

Local distribution. Kiushin (Tanegashima, Yakushima).

General distribution. Japan; Loochoo; Formosa; China; Malay; India.

Pyrameis cardui.

Nymphalis cardui Linn. Syst. Nat. 10 ed. p. 475; Moore, Lep. Ceyl. I. p. 50, pl. 27. figs. 1, 1 a; Pryer, Rhop. Nihon. p. 26, pl. 7. f. 2; Leech, Butt. Chin. Jap. Cor. I. p. 251; Stichel, Seitz, Macrolep. I. p. 199, pl. 62 d; Niré, Dobuts-zas. 1918, Suppl. p. 14.

Pyrameis cardui japonica Stichel, Seitz, Macrolep. I. p. 200, pl. 62 d (1909). Recorded by Iwata.

Local distribution. Hokkaido; Honshiu; Shikoku; Kiushu.

General distribution. Cosmopolitan.

Vanessa canace.

Papilio canace Johans. Centur. Ins. p. 23 (1763); Moore, Lep. Ind. IV. p. 92, pl. 315. figs. 1, 1 a, ♂. ♀; Leech, Butt. Chin. Jap. Cor. I. p. 255; Miyajima, Nihon-chor. p. 113, pl. 10. f. 8; Stichel, Seitz, Macrolep. I. 206.

Vanessa no-japonica Siebold, Hist. Nat. Jap. p. 16 (1824).

Vanessa glauconia Moore, P. Z. S. 1879, p. 137.

Vanessa canace ishima Fruhst. Stett. Ent. Zeit. p. 416 (1894).

Vanessa canace drilon Fruhst. Ent. Wochenb. p. 41 (1908).

Vanessa charonides Stichel, Seitz, Macrolep. I. p. 206, pl. 63 e (1906).

Vanessa canace siphnos Fruhst. Seitz, Macrolep. IX. p. 527 (1912).

A female of the *no-japonica* form by Habutsu in Yakushima, August 1910. Recorded also by Iwata.

Local distribution. Hokkaido; Honshiu; Shikoku; Kiushiu.

General distribution. Japan; Loochoo; Corea; Formosa; China; India.

Argynnis nerippe.

Argynnis nerippe Feld. Wien. Ent. Mon. VI. p. 24 (1862); Pryer, Rhop.

Nihon. p. 23, pl. 8. f. 1 A, B ; Leech, Butt. Chin. Jap. Cor. I. p. 234,
pl. 22. figs. 7, 8 ; Seitz, Seitz, Macrolep. I. p. 239, pl. 69 f ; Niré, Do-
butsu-zas. 1918, Suppl. p. 6.

Argynnis coreana Butl. A. M. N. H. (5) IX. p. 15 (1882.

Argynnis chlorotis, agrippina, megalothymus Fruhst. Soc. Ent. XXII. p. 68 (1908).
Recorded by Iwata.
Local distribution.   Hokkaido ; Honshiu ; Shikoku ; Kiushiu.
General distribution.   Japan ; Corea ; China ; Tibet ; Siberia.

Argynnis sagana.

Argynnis sagana Doubleday, Gen. Diurn. Lep. pl. 24. f. 1 (1847) ; Pryer,
Rhop. Nihon. p. 23, pl. 8. f. 3, ♂, pl. 10. fig. 24, ♀ ; Leech, Butt. Chin.
Jap. Cor. I. p. 241 ; Seitz, Seitz, Macrolep. I. p. 249, pl. 71 b ; Niré,
Dobutsu-zas. 1918, Suppl. p. 18.

Damora paulina Nord. Bull. Mosc. II. p. 440, pl. 11. figs. 1, 2 (1851).

Argynnis sagana liana, ilona Fruhst. Soc. Ent. XXII. p. 67 (1907).
Recorded by Iwata.
Local distribution.   Hokkaido ; Honshiu ; Shikoku ; Kiushiu.
General distribution.   Japan ; Corea ; China ; Siberia.

Argynnis hyperbius.

Papilio hyperbius Johansen, Amoen. Acad. VI. p. 408,   (1764) ; Niré, Dobu-
tsu-zas. 1918, Suppl. p. 5.

Nymphalis niphe Linn. Syst. Nat. 12 ed. p. 785 (1767).

Acidalia taprabana Moore, Lep Ind. IV. p. 237 (1899-1900).

Argynnis niphe var. *castelsi* Oberth. Bull. Soc. Ent. Fr. 1889, p. 235.
Very common.
Local distribution.   Honshiu , Shikoku ; Kiushiu.
General distribution.   Japan ; Loochoo ; Formosa ; China ; Java ; Suma-
tra ; India.

Fam. Asciadae.

Hebomoia glaucippe.

Danaus glaucippe Linn. Syst. Nat. 10 ed. p. 469 (1758) ; Moore, Lep. Ceyl.

I. p. 127, pl. 49. figs. I, I a, I b. ? , larva and pupa; Fritze, Liu-
Kiu-Ins. p. 38; Fruhst. Seitz, Macrolep. IX. p. 175.

Hebomoia australis Butl. A. M. N. H. (7) I. p. 260 (1898).

Hebomoia glaucippe linkiuensis Frulst. Berl. Ent. Zeitschr. p. 172 (1898).

Hebomoia glaucippe conspicua Fruhst. Deut. Ent. Zeit. Iris, XXI. p. 92 (1907).

Hebomoia glaucippe formosana Fruhst. Ent. Zeitschr. Stuttg. p. 102 (1908).

Hebomoia glaucippe cinica, aturia, anaxandra, crinea Fruhst. Seitz, Macrolep.
IX. p. 175-176 (1910).

Not uncommon in Tanegashima and Yakushima from July to August.
They all belong to the *linkiuensis* form.

Local distribution.   Kiushiu (Yakushima, Tanegashima).

General distribution.   Japan, Loochoo; Formosa; China; Malay; India.

Pieris rapae.

Papilio rapae Linn. Syst. Nat. 10 ed. p. 468 (1758); Pryer, Rhop. Nihon.
p. 6, pl. 3. f. 6; Leech. Butt. Chin. Jap. Cor. II. p. 456; Röber, Seitz,
Macrolep. I. p. 46, pl. 20 e; Niré, Dobutsu-zas. 1916, Suppl. p. 63.

Pieris brassicae var. *crucivora* Boisd. Gén. p. 522 (1836).

Pieris rapae var. *orientalis* Oberth. Etud. Ent. V. p. 13 (1880).

Pieris rapae var. *mandschrica* Speyer, Stett. Ent. Zeit. 1882, p. 379.

Pieris rapae dubiosa, flavescens, vilniensis Röber, Seitz, Macrolep. I. p. 46
(1907).

Very common.

Local distribution.   Hokkaido; Honshiu; Shikoku; Kiushiu.

General distribution.   Japan; Corea; Saghalin; China; Siberia; Europe.

Pieris melete.

Pieris melete Mén. Cat. Mus. Petr. II. p. 113, pl. 10. figs. 1, 2 (1857); Leech,
Butt. Chin. Jap. Cor. II. p. 448; Röber, Seitz, Macrolep. I. p. 47, pl.
21 b; Niré, Dobutsu-zas. 1916, Suppl. p. 62.

Pieris aglaope Motsch. Etud Ent. IX. p. 28 (1860).

Pieris napi Pryer (nec Linn.), Rhop. Nibon. p. 6, pl. 3. f. 8 b (1886).

Pieris rapae var. *mandarina* Leech, Butt. Chin. Jap. Cor. II. p. 451.

Synchloe megamera Butl. Cist. Ent. I. p. 173 (1873).

Ganoris dulcinea Butl. A. M. N. H. (5) IX. p. 18 (1882).

Pieris melete massica, jub. Fruhst. Seitz, Macrolep. IX. p. 140 (1910).

    Recorded by IWATA.

    Local distribution. Hokkaido; Honshiu; Shikoku; Kiushiu.

    General distribution. Japan; Corea; Saghlin; Siberia; China; India; Europe.

Anthocharis scolymus.

Anthocharis scolymus Butl. Journ. Sec. Linn. Zool. IX. p 52 (1866); Pryer, Rhop. Nihon. p. 6, pl. 3. figs. 4 a, b; Leech, Butt. Chin. Jap. Cor. II. p. 479; Röber, Seitz, Macrolep. 1. p. 55, pl. 23 a; Niré. Dobutsu-zas 1917, Suppl. p. 4.

Anthocharis thunbergii de l'Orza, Lep. Jap. p. 14 (1869).

Midea scolymus ab. *virgo* Röber, Seitz, Macrolep. 1. p. 55 (1907).

    Recorded by IWATA.

    Local distribution. Hokkaido; Honshiu; Shikoku; Kiushin.

    General distribution. Japan; China.

Eurema laeta.

Terias laeta Boisd. Spec. Gén. Lép. p. 674 (1836); Pryer, Rhop. Nihon. p. 10, pl. 2. f. 10; Leech, Butt. Chin. Jap. Cor. II. p. 425; Röber. Seitz. Macrolep. I. p. 58, pl. 23 e; Fruhst. Seitz. Macrolep. IX. p 166, pl. 73 d; Niré, Dobutsu-zas, 1917, Suppl. p. 9.

Terias bethesba Jans. Cist. Ent. II. p. 272 (1878).

Terias subferrens Butl. A. M. N. H. (5) XI. p. 258 (1883).

Terias biformis Pryer, Rhop. Nihon. p. 21 (1888).

    Seven males of the *bethesba* form taken by MIYAKE. Recorded also by IWATA.

    Local distribution. Honshiu; Shikoku; Kiushiu.

    General distribution. Japan; Locchoo; Formosa; Corea; China; Malay; India.

Eurema hecabe.

Danaus hecabe Linn. Syst. Nat. 10 ed. p. 470 (1758); Leech, Butt. Chin. Jap. Cor. II. p. 428; Fritze, Faun. Liu-Kiu-Ins. p. 35. figs. 9-11; Röber,

Seitz, Macrolep. I. p. 59, pl. 23 f; Niré, Dobutsu-zas. 1917, Suppl. p. 8.

Terias mariformis Pryer, Trans. Ent. Soc. p. 189 (1882).

Terias nadarina de l'Orza, Jap. p. 18 (1869).

Terias moriesii Butl. Trans. Ent. Soc. 1880, p. 198, pl. 7. figs. 1-7.

Terias hybrida Butl. Trans. Ent. Soc. 1880, p. 199, pl. 6. f. 7.

Terias connexiva Butl. Trans. Ent. Soc. 1880, p. 199, pl. 6. f. 12.

Terias anemone Feld. Wien. Ent. Mon. VI. p. 23 (1862).

Terias hobsoni Butl. P. Z. S. 1880, p. 668.

Terias mandarigera Butl. P. Z. S. 1880, p. 668.

Very common.

Local distribution. Honshu ; Shikoku ; Kiushiu.

General distribution. Japan ; Loochoo ; Formosa ; Malay ; India.

Colias hyale.

Papilio hyale Linn. Syst. Nat. 10 e I. p. 469 (1758) ; Pryer, Rhop. Nihon. p. 8, pl. 2. f. 4 B ; Leech, Butt. Chin. Jap. Cor. II. p. 431, pl. 34. figs. 3, 4, 6, 10, 11, 12, 14 ; Fritze, Faun. Liu-Kiu-Ins. p. 38 ; Miyake, Ann. Zool. Jap. VI. p. 25 ; Röber, Seitz, Macrolep. I. p. 65, pl. 25 g ; Niré, Dobutsu-zas. 1917, Suppl. p. 1.

Colias poliographus Motsch. Etud. Ent. IX. p. 29 (1860).

Colias pallens Butl. Journ. Linn. Soc. Zool. IX. p. 52 (1866).

Colias simoda de l'Orza, Lep. Jap. p. 16 (1869).

Colias cheesii Butl. A. M. N. H. (5) VII. p. 138 (1881).

Colias subaurata Butl. A. M. N. H. (5) VII. p. 138 (1881).

Colias hyale ab. *emarginata* Röber, Seitz, Macrolep. I. p. 65 (1907).

Very common.

Local distribution. Hokkaido ; Honshiu ; Shikoku ; Kiushiu.

General distribution. Japan ; Loochoo ; Formosa ; Corea ; China ; Siberia ; Europe.

Fam. **Cupidinidae.**
Arhopala japonica.

Amblypodia japonica Murray, Ent. Mon. Mag. XI. p. 170 (1875) ; Pryer,

Rhop. Nihon. p. 11, pl. 2. f. 14; Leech, Butt. Chin. Jap. Cor. II. p. 344,
pl. 30. f. 14; Miyajima, Nihon-Chor. p. 173, pl. 19. f. 6; Seitz, Seitz,
Macrolep. I. p. 274, pl. 75 b.

Arhopala japonica var. *horishana* Matsumura, Ent. Zeitschr. Stuttg. XXII. p.
221 (1910).

Five males and a female taken by MIYAKE in Tanegashima.   Recorded
also by IWATA.

Local distribution.   Honshiu; Shikoku; Kinshiu.

General distribution.   Japan; Loochoo; Formosa: Corea.

Arhopala bazalus.

Amblypodia bazalus Hew. Cat. Lyc. B. M. p. 8, pl. 4. figs. 37, 38 (1862);
Moore, Journ. Asiat. Soc. Bomb. LIII. p. 39; Niré, Dobutsu-zas, 1819,
Suppl. p. 22.

Amblypodia turbata Butl. P. Z. S. 1881, p. 855; Pryer, Rhop. Nihon p. 11,
pl. 11. f. 16; Leech, Butt. Chin. Jap. Cor. II. p. 345; Miyajima, Nihon-
Chor. p. 173, pl. 19. figs. 4, 5; Seitz, Seitz, Macrolep. I. p. 275.

Satadra teesta Nicév. Journ. Asiat. Soc. Beng. LV. p. 253, pl. 11. f. 3 (1886).
Two males taken by MIYAKE.   Recorded also by IWATA.

Local distribution.   Honshiu; Shikoku; Kinshiu.

General distribution.   Japan; Corea; India.

Curetis acuta.

Curetis acuta Moore, A. M. N. H. (4) XX. p. 50 (1877); Pryer, Rhop. Nihon.
p. 11, pl. 4. figs. 1, 2; Leech, Butt. Chin. Jap. Cor. II. p. 349; Miya-
jima, Nihon-Chor. p. 176, pl. 19. figs. 9, 10; Seitz, Seitz, Macrolep. I.
p. 276.

Anops phaedrus de l'Orza, Lep. Jap. p. 22 (1869).

Curetis truncata Moore, A. M. N. H. (4) XX. p. 50 (1877).

Curetis paracuta Nicév. Journ. Bomb. Nat. Hist. Soc. XIV. p. 248 (1901);
Wileman, Philip. Journ. Scien. X. p. 297, pl. 2. figs. 18-22.

Curetis acuta japonica, tsushimana Fruhst. Stett. Ent. Zeit. 1908, pp. 56, 57.

Curetis acuta formosana Fruhst. Ent. Zeitschr. Stuttg. XXII. p. 46 (1908).

Curetis acuta lucifuga Fruhst. S. e. Ent. XXIV. p. 12 (1909).

A male of the *paraenbe* form taken by me at Nishinoomote, Tanegashima, July 23, 1918. Occurs also in Yakushima. Recorded by IWATA.

Local distribution. Honshiu; Shikoku; Kiushiu.

General distribution. Japan; China; India.

Polyommatus boeticus.

Plebejus boeticus Linn. Syst. Nat. 12 ed. 789 (1767); Moore, Lep. Ceyl. I. p. 93; Distant, Rhop. Malay. p. 214, fig. 64, p. 320, pl. 20, figs. 1, 8; Leech, Butt. Chin. Jap. Cor. II, p. 327; Miyajima, Nipon-Chor. p. 171, pl. 19, f. 3; Seitz, Seitz, Macrolep. I. p. 291, pl. 77 h.

Lycaena boetica Lang, Butt. Eur. p. 99, pl. 22, f. 2 (1884).

A female taken by me at Noma, Tanegashima, June 12, 1919. Recorded also by IWATA.

Local distribution. Honshiu; Shikoku; Kiushin.

General distribution. Japan; Loochoo; Formosa; China; Philippines; Malay; India; Africa; Australia; Europe.

Nacaduba atrata.

Lycaena atrata Horsfield, Cat. Lep. Mus. E. I. C. p. 78 (1828); Moore, Lep. Ceyl. I. p. 89; Davidson, Bell and Atkinson, Journ. Bom. Nat. Hist. Soc. p. 576, pl. 4 figs. 2, 2 a, larva and pupa; Bingham, Butt. Ind II. p. 488.

Lycaena kurava Moore, Cat. Lep. Mus. E. I. C. I. p. 22 (1857).

Lampides prominens Moore, A. M. N. H. (4) XX. p. 341 (1877).

A male specimen taken by MIYAKE in Yakushima. Recorded also by IWATA as common in this district.

Local distribution. Kiushin (Yakushima and Tanegashima).

General distribution. Japan; Loochoo; Formosa; Malay; India.

Zizera maha.

Lycaena maha Koll. Hüg. Kasch. IV. p. 422 (1848); Leech, Butt, Chin. Jap. Cor. II, p. 325; Miyajima, Nihon-Chor. p. 168, pl. 18, f. 13; Seitz, Seitz, Macrolep. I. p. 295, pl. 79 c.

Lycaena argia Mén. Cat. Mus. Petr. II, p. 125, pl. 10. f. 7 (1857).

Polyommatus chandala Moore, P. Z. S. 1867, p. 504, pl. 31. f. 5.

Lycaena japonica Murray, Ent. Mon. Mag. XI. p. 167 (1874).

Lycaena diluta Feld. Nov. Reise, II, p. 280, pl. 35. figs. 12, 13 (1865).

Lycaena squalida Butl. Trans. Ent. Soc. 1879, p. 4.

Lycaena alope Fenton, P. Z. S. 1881, p. 351.

Zizera ossa Swinhoe, P. Z. S. 1885, p. 132, pl. 9. figs. 11, 12.

Lycaena opdiva Ponj. Ann. Soc. Ent. Fr. 1885, p. 143.

Lycaena marginata Ponj. Ann. Soc. Ent. Fr. 1885, p. 151.

> Very common. All are the *argia* form.
>
> Local distribution. Honshiu; Shikoku; Kiushiu.
>
> General distribution. Japan; Loochoo; Formosa; Corea; China; India.

Everes argiades.

Papilio argiades Pallas, Reise, 1. App. p. 472 (1771); Elwes, P. Z. S. 1881, p. 887; Pryer, Rhop. Nihon. p. 17, pl. 4, figs. 29 a, b; Leech, Butt. Chin. Jap. Cor. II, p. 328. Miyajima, Nihon-Chor. p. 170, pl. 19. figs. 1, 2; Seitz, Seitz, Macrolep. I. p. 297, pl. 78 a.

Hespera parrhasius Fabr. Ent. Syst. III. p. 289 (1793).

Lycaena hellotia Méw. Cat. Mus. Petr. II. p. 124, pl. 10. f. 6 (1857).

Lycaena dipora Moore, P. Z. S. 1865, p. 506, pl. 31. f. 8.

> Recorded by IWATA.
>
> Local distribution. Hokkaido; Honshiu; Shikoku; Kiushiu.
>
> General distribution. Japan; Loochoo; Formosa; Corea; Siberia; China; India; Australia; Europe; N. America.

Cyaniris argiolus.

Plebejus argiolus Linn. Syst. Nat. 10 ed. p. 483 (1758); Pryer, Rhop. Nihon. p. 18, pl. 4. figs. 25 a, b; Leech, Butt. Chin. Jap. Cor. II. p. 320; Miyajima, Nihon-Chor. p. 167, pl. 18, f. 12; Seitz, Seitz, Macrolep. I. p. 322, pl. 83 g, h.

Lycaena coelestina Koll. Hüg. Kasch. IV. p. 423 (1848).

Lycaena ladon Mén. Cat. Lep. Mus. Petr. II. p. 124, pl. 10, f. 5 (1857).

Polyommatus kasmira Moore, P. Z. S. 1865, p. 503, pl. 31, f. 1.

Lycaena ladonides de l'Orza, Lep. Jap. p. 20 (1867).

Lycaena levetti Butl. A. M. N. H. (5) XI. p. 111 (1883).

Cyaniris lucy lii Moore, P. Z. S. 1882, p. 244.

Two males and females taken by me on Mt. Miyanoura, Yakushima, July 18, 1918, and at Furuta, Tanegashima, June, 19, 1919. It seems that the species is very common on Mt. Miyanoura.

Local distribution. Hokkaido; Honshiu; Shikoku; Kiushiu.

General distribution. Japan; Loochoo; Formosa; Corea; Siberia; India; Africa; Europe.

Taraka hamada.

Melitis hamada Druce, Cist. Ent. 1. p. 371 (1875); Pryer, Rhop. Nihon. p. 10, pl. 2. f. 12; Leech, Butt. Chin. Jap. Cor. II. p. 293; Miyajima, Nihon-Chor. p. 160, pl. 18. f. 1; Seitz, Seitz, Macrolep. I. p. 323, pl. 83 f, g.

Two males taken by MIYAKE in Tanegashima.

Local distribution. Honshiu; Shikoku; Kiushiu.

General distribution. Japan; China; Java; Malay; India.

Fam. **Plebejidae.**

Subfam. LIBYTHEINÆ.

Libythea celtis.

Papilio celtis Fuessly, Arch. Ins. pl. 8, figs. 1-3. (1782); Seitz, Seitz, Macrolep. I p. 251, pl. 71 f.

Libythea lepida Moore, Cat. Mus. E. I. C. I. p. 240 (1857).

Libythea lepidoides Moore, Lep. Ind. V. p. 57, pl. 394. figs. 1, 1 a-1 c, ♂ (1901-1903).

Recorded by IWATA.

Local distribution. Hokkaido, Honshiu; Shikoku; Kiushiu.

General distribution. Japan; India; Asia Minor; Europe.

Fam. EQUITIDÆ

Eques alcinous.

Papilio alcinous Klug. Neue Schmett. p. 1, pl. 1. figs. 1-4 (1836); Pryer, Rhop. Nihon. p. 4, pl. 3. f. 3; Leech, Butt. Chin. Jap. Cor. II. p. 539;

Seitz, Seitz, Macrolep. I. p. 9, pl. 2 a, b ; Wileman, Philip. Journ. Scien.
IX. p. 255, p'. 2. figs. 12–16, larva ; Niré, Dobutsu-zas. 1916, Suppl.
p. 54.

Papilio mencius Feld. Wien. Ent. Mon. VI. p. 22 (1862).

Papilio spathatus Butl. A. M. N. H. (5) VII. p. 139 (1881).

Papilio hæmatostictus Butl. A. M. N. H. (5) VII. p. 139 (1881).

Papilio alcinous loochooanus Rothsch. Novit. Zool. II. p. 271 (1895).

Papilio alcinous mansonensis Fruhst. Soc. Ent. XVI. p. 113 (1901).

Papilio alcinous nagisaki Fruhst. Soc. Ent. XXI. p. 74 (1906).

Papilio plutonius Miyake (nec Oberth.), Dobutsu-zas. 1906, p. 148, p. 148,
f. 5, pl. 4. f. 13.

Papilio alcinous bradanus Fruhst. Ent. Zeitschr. Stuttg. XXII. p. 46 (1908).

Papilio ikusa Ehrman, Canad. Entom. XLI. p. 85 (1909).

Recorded by IWATA.

Local distribution. Honshiu ; Shikoku ; Kiushiu

General distribution. Japan ; Loochoo ; Formosa ; China.

Eques protenor.

Papilio protenor Cram. Pap. Exot. I. p. 77 (1777) ; Leech, Butl. Chin. Jap.
Cor. II. p. 545 ; Miyake, Dobutsu-zas. 1906, p. 78. pl. 1. f. 1.

Papilio demetrius Cram. Pap. Exot. IV. p. 196, pl. 385. figs. E, F (1782).

Papilio carpenteri Butl. A. M. N. H. (5) X. p. 318 (1882).

Papilio demetrius liukiuensis Fruhst. Stett. Ent. Zeit. p. 407 (1898).

Papilio demetrius sitalkes Fruhst. Ent. Zeitschr. Stuttg. XXII. p. 46 (1908).

Papilio protenor amaura Jord. Seitz, Macrolep. IX. p. 75 (1909).

Papilio protenor taiwanus Matsumura, Dobutsu-zas. 1909, p. 390.

A male of the *demetrius* form taken by MIYAKE in Tanegashima. Re-
corded also by IWATA.

Local distribution. Honshiu ; Shikoku ; Kiushiu.

General distribution. Japan ; Loochoo ; Formosa ; Malay ; India.

Eques memnon.

Eques memnon Linn. Syst. Nat. 12 ed. p. 747 (1767) ; Pryer, Rhop. Nihon.

p. 4; Leech, Butl. Chin. Jap. Cor. II. p. 514; Fritze, Faun. Liu-Kiu
Ins. p. 28, figs. 3, 4; Niré, Dobutsu-zas. 1906, Suppl. p. 60.

Eques cignor Linn. Syst. Nat. 10 ed. p. 460 (1758).

Papilio alcanor Cram. Pap. Exot. II. p. 107 (1777).

Papilio thunbergi Sieb. Hist. Nat. Jap. p. 16 (1824).

Papilio androgeos Wall. (nec Cram.), P. Z. S. p. 356 (1866).

Papilio memnon pryeri Roth ch. Novit. Zool. II. p. 313 (1895).

Papilio memnon distantianus Roth ch. Novit. Zool. II. p. 320 (1895).

Papilio memnon heronus Fruhst. Soc. Ent. XVII. p. 73 (1902).

Papilio memnon titania Jordan, Seitz, Macrolep. IX. p. 73 (1909).

Very common in Yakushima and Tanegashima. All are *thunbergi* form.
Local distribution. Shikoku; Kiushiu.

General distribution. Japan; Loochoo; Formosa; China; Philippines;
Java; Borneo; Malay; India.

Eques bianor.

Papilio bianor Cram. Pap. Exot. II. p. 10, pl. 103. f. e. (1777); Pryer, Rhop.
Nihon. p. 3; Leech, Butl. Chin. Jap. Cor. II. p. 527.

Papilio dehaanii Feld. Verh. Zool.-Bot. Ges. Wien, XIV. pp. 323, 371 (1864).

Papilio bianor var. *japonica* Butl. Journ. Linn. Soc. Zool. IX. p. 50 (1866).

Papilio alliaceaon de l'Orza, Lep. Jap. p. 9 (1869).

Papilio maacki Pryer (nec Mén.), Rhop. Nihon. p. 3 (1886).

Papilio bianor okinawensis Fruhst. Soc. Ent. No. 10 (1898).

Papilio bianor junia Jordan, Seitz, Macrolep. IX. p. 78 (1909).

Papilio bianor formosanus Rebel, Verh. Zool.-bot Ges. Wien, LXI. p. 222
(1905).

Recorded by IWATA.

Local distribution. Hokkaido; Honshiu; Shikoku; Kiushiu.

General distribution. Japan; Loochoo; Formosa; Corea; China; Siberia;
Burma.

Eques helenus.

Eques helenus Linn. Syst. Nat. 12 ed. p. 745 (1767); Pryer, Rhop. Nihon. p.

4. pl. 2. f. 2 ; Leech, Butl. Chin. Jap. Cor. II. p. 548 ; Frite. Faun. LivKiu-Ins. p. 27.

Papilio nicomicolens Butl. A. M. N. H. (5) VII. p. 139 (1881).

Papilio helenus semans Fruhst. Entom. Wochenb. p. 38 (1908).

Papilio helenus orosius Fruhst. Entom. Wochenb. p. 38 (1908).

Papilio helenus fortunius Fruhst. Entom. Wochenb. p. 38 (1908).

MIYAKE took five males and three females in Tanegashima, August 1909, and I also took a male of the *nicomicolens* form at Kusakawa, Yakushima, July 21, 1918. Recorded by IWATA.

Local distribution. Honshiu ; Shikoku ; Kiushiu.

General distribution. Japan ; Loochoo ; Formosa ; China ; Philippines ; Malay ; India.

Eques xuthus.

Eques xuthus Linn. Syst. Nat. 12 ed. p. 751 (1767) ; Pryer, Rhop. Nihon. p-3, pl. 1. f. 2 b ; Leech, Butt. Chin. Cor. II. p. 514 ; Seitz, Seitz, Macro. lep. I. p. 11, pl. 6 a ; Niró, Dobutsu-zas. 1916, Supple. p. 51.

Papilio xuthulus Brem. Bull. Acad. Petr. III. p. 463 (1861) ; Lep. Ost-Sib. pl. 1. f. 2.

Papilio xuthus hoxinga Fruhst. Ent Zeitschr. Stuttg. XXII. p. 46 (1908).

Six males and a female taken by MIYAKE in Tanegashima. Recorded also by IWATA.

Local distribution. Hokkaido ; Honshiu ; Shikoku ; Kiushiu.

General distribution. Japan ; Saghalin ; Corea ; Loochoo ; Formosa , China ; Siberia ; Burma.

Eques machaon.

Eques machaon Linn. Syst. Nat. 10 ed. p. 462 (1758) ; Pryer, Rhop. Nihon. p. 3, pl. 1. f. 1 b ; Leech, Butl. China. Jap. Cor. II. p. 516 ; Seitz, Seitz, Macrolep. I. p. 12, pl. 6 e ; Niró, Dobutsu-zas. 1916, Suppl. p. 51.

Papilio sphyrus Hübn. Exot. Schmett. figs. 775, 776.

Papilio machaon asiatica Mén. Cat. Mus. Peter. Lép. I. p. 70 (1855).

Papilio hippocrates Feld. Verh. Zool.-bot. Ges. Wien, XIV. pp. 314, 362 (1864).

Papilio mikado Pagenst. nec Leech, Verh. Ver. Heidelb. (2) I. p. 98 (1875).

Papilio ladakensis Moore, Journ. Asiat. Soc. Beng. 1884, p. 46.

Papilio sikkimensis Moore, Journ. Asiat. Soc. Beng. 1884, p. 47.

Papilio machaon var. sagadlioensis Matsumura, Journ. Coll. Agr. Sapporo, IV. p. 40 (1911).

A female taken by MIYAKE in Tanegashima, August 1909. Recorded also by IWATA.

Local distribution. Hokkaido; Honshiu; Shikoku; Kiushiu.

General distribution. Japan; Corea; Saghalin; China; India; Europe.

Eques sarpedon.

Eques sarpedon Linn. Syst. Nat. 12 ed. p. 747 (1767); Pryer, Rhop. Nihon. p. 5, pl. 1. f. 9; Leech, Butl. Chin. Jap. Cor. II. p. 524; Fritze, Faun. Liu-Kiu-Ins. p. 39; Seitz, Seitz, Macrolep. I. p. 15, pl. 8 c; Wileman, Philip. Journ. Scien. IX. p. 252, pl. 9. figs. 6-8, larva.

Papilio sarpedon var. semifasciatus Hon. Ent. Nach. 1883, p. 161.

Papilio sarpedon connectens Fruhst. Soc. Ent. XXI. p. 73 (1906).

Papilio sarpedon nipponus, morius, sarpedonides Fruhst. Ent. Zeitschr. Stuttg. XXII, p. 46 (1908).

Papilio suzusumi Matsumura, Ent. Zeitschr. Stuttg. XXIII. p. 209 (1910).

Very common in Tanegashima and Yakushima.

Local distribution. Hokkaido; Honshiu; Shikoku; Kiushiu.

General distribution. Japan; Loochoo; Formosa; Corea; China; Philippines; Java; Borneo; Sumatra; Malay; Amboina; New-Guinea.

Fam. Erynnidæ.

Rhopalocampta benjamini.

Thymele benjamini Guér. Deless. Souv. Voy. Inde, II. p. 79, pl. 22. figs. 2, 2 a (1843); Leech, Butl. Chin. Jap. Cor. II. p. 641; Miyajima, Nihon-Chor. p. 206, pl. 22. f. 11; Mabille, Seitz, Macrolep. I. p. 341, pl. 86 e.

Isemene benjamini var. japonica Murray, Ent. Mon. Mag. XII. p. 4 (1875).

Three males taken by MIYAKE. Recorded also by IWATA.

Local distribution. Hokkaido; Honshiu; Shikoku; Kiushiu.

General distribution. Japan; Loochoo; Formosa; China; India.

Parnara mathias.

Hesperia mathias Fabr. Ent. Syst. Suppl. p. 433 (1798); Moore, Lep. Ceyl.
    I. p. 168, pl. 70. figs. 1, 1 a; Distant, Rhop. Malay. p. 380, pl. 35. f.
    10; Pryer, Rhop. Nihon. p. 33, pl. 10. f. 7; Leech. Butl. Chin. Jap.
    Cor. II. p. 606; Miyajima, Nihon-Chot. p. 201, pl. 32. f. 4; Mabille,
    Seitz, Macrolep. I. p. 349, pl. 88 f. g.

Very common.

Local distribution. Honshiu; Shikoku; Kiushiu.

General distribution. Japan; Loochoo; Formosa; China; Java; Malay;
India; Aden.

Padraona flava.

Pamphila flava Murr. Ent. Mon. Mag. XII. p. 4 (1875); Pryer, Rhop.
    Nihon. p. 35, pl. 10. f. 17; Mabille, Seitz, Macrolep. I. p. 351.

Pamphila japonica Mabille, Ann. Soc. Ent. Belg. XXVIII (1883).

Padraona dara (part) Leech (nec Koll.), Butl. Chin. Jap. Cor. II. p. 596,
    pl. 40. figs. 13, 14 (1894).

A male taken by MIYAKE, August 1909. A male and a female also
taken by me at Nishinoomote, Tanegashima, July 26, 1918.

Local distribution. Honshiu; Shikoku; Kinshiu.

Habitat. Japan.

Notocrypta currifascia.

Plesioneura currifascia Feld. Wien. Ent. Mon. VI. p. 29 (1862); Leech.
    Butl. Chin. Jap. Cor. II. p. 626, pl. 38, f. 1; Miyajima, Nihon-Chot. p,
    205, p. 22. f. 9; Mabille, Seitz, Macrolep. I. p. 253, pl. 84 g.

Seven males and two females taken by HABUTSU in Yakushima, August
1910. Recorded also by IWATA.

Local distribution. Kiushiu.

General distribution. Japan; Loochoo; Formosa; China.

Fam. **Zygænidæ.**

Subfam. CHALCOSIANÆ.

Procris tristis.

Procris tristis Brem. Lep. Ost-Sib. p. 97, pl. 8. f. 4 (1864) ; Leech, Trans.
Ent. Soc. 1898, p. 331 ; Staud. Cat. Lep. pal. p. 390.

Procris esmeralda Butl. A. M. N. H. (4) XX. p. 394 (1877) ; Ill. Het. B. M.
II. p. 4, pl. f. 8.

Procris pruni (part) Jord. Seitz, Macrolep. II. p. 6 (1912).

A male and two females taken by HABUTSU in Tanegashima, September
1910.

Local distribution. Honshiu ; Kiushiu.

General distribution. Japan ; Corea ; China ; Siberia.

Heterusia œdea.

Heliconius œdea Linn. Syst. Nat. 10 ed. p. 757 (1758) ; Kirby, Cat. Het. I.
p. 50 ; Hmpsn. Moths. Ind. 1. p. 262 ; Leech, Trans. Ent. Soc. 1898. p.
342 ; Jord. Seitz, Macrolep. II. p. 10, pl. 2 e.

I have seen two examples which were on wings near Nishinoonte,
Tanegashima, June 1919, but failed to take them.

Local distribution. Honshiu ; Kiushiu.

General distribution. Japan ; Loochoo ; China ; India.

Erasmia pulchella.

Erasmia pulchella Hope, Trans. Linn. Soc. Lond. XVII. p. 466, pl. 31. f. 5
(1840) ; Hmpsn. Moths Ind. I. p. 273 ; Fritze, Faun. Liu-Kiu-Ins. p.
64 ; Leech, Trans. Ent. Soc. 1898 ; p. 346 ; Jord. Seitz, Macrolep. II.
p. 12.

Erasmia pulchella subsp. *chinensis* Jord. Seitz, Macrolep. II. p. 12, pl. 2 g
(1912).

A male of the *chinensis* form taken by HABUTSU in Yakushima, August
1909 and there is another male from the same locality in my collection.

Local distribution. Kiushiu.

General distribution.   Japan ; Loochoo ; China ; India.

Fam. **Caliidulidæ**.

Callidula formosana.

(Pl. III. fig. 6.)

Callidula formosana Wileman, Entom. 1910, p. 290.

A female taken by me in Yakushima, July 13, 1918 and another female by HABUTSU, August 1910. I have also seen this species which was on wings at Tanegashima, June 1919.

Local distribution.   Kiushiu (Yakushima ; Tanegashima).

General distribution.   Japan ; Formosa.

Fam. **Drepanidæ**.

Deroca phasma.

Deroca phasma Butl. A. M. N. H. (5) I. p. 442 (1878) ; Ill. Het. B. M. III. p. 49, pl. 53. f. 4 ; Nagano, Butt. Nawa Ent. Lab. II. p. 127. pl. 3. f. 15, pl. 9. figs. 16—20.

Deroca inconclusa (Part) Leech, Trans. Ent. Soc. 1898, p. 370 ; Strand, Seitz, Macrolep. II. p. 203, pl. 48 c.

A male taken by me on Mt. Miyanoura, Yakushima, July 18, 1918.

Local distribution.   Honshiu ; Kiushiu.

Habitat.   Japan.

Fam. **Pyralidæ**.

Subfam.   TINEINÆ.

Lamoria inostentalis.

Maracea inostentalis Wlk. Cat. XXVII. p. 88 (1863) ; Leech, Trans. Ent. Soc. 1901, p. 387 ; Hmpsn. Novit. Zool. 1917. p. 51.

A female taken by HABUTSU in Yakushima, August 1910.

Local distribution.   Hokkaido ; Honshiu ; Kiushiu.

General distribution.   Japan ; Formosa ; Corea ; China ; Borneo ; D'entre-
casteaux Is.

Subfam. CRAMBINÆ.

Crambus diplogrammus.

Crambus diplogrammus Zell. Chil. et Cramb. p. 25 (1863) ; Leech, Trans. Ent.
    Soc. 1901, p. 388.

Two males taken by me on Mt. Miyanoura, Yakushima, July 16, 17,
1918.

Local distribution.   Honshiu ; Kiushiu.

General distribution.   Japan ; China ; Siberia.

Crambus argyrophorus.

Crambus argyrophorus Butl. Ill. Het. B. M. II. p. 61, pl. 40. f. 5 (1878) ;
    Hmpsn. Moths Ind. IV. p. I5 ; Leech, Trans. Ent. Soc. 1901, p. 392.

A male measuring in expanse 17 mm. taken by me at Miyanoura, Yaku-
shima, July 12, 1918.

Local distribution.   Honshiu ; Kinshiu.

General distribution.   Japan ; China ; India.

Ancylolomia chrysographella.

Chilo chrysographella Koll. Hüg. Kasch. IV. p. 494 (1844) ; Hmpsn. Moths
    Ind. IV. p. 33 ; Leech, Trans. Ent. Soc. 1901, p. 399.

Ancylolomia taprobanensis Zell. Hor. Ent. Ross. 1877, p. 25, pl. 1. f. 8 ; Moore,
    Lep. Ceyl. III. p. 381, pl. 184. figs. 2, 2 a.

Ancylolomia capensis Zell. Chil. et Cramb. p. 11.

Ancylolomia indica Feld. Reise Nov. Lep. pl. 137. f. 19 (1874).

Ancylolomia argentata Moore, Lep. Ceyl. III. p. 382, pl. 184. f. 3.

A male taken by me on Mt. Miyanoura, Yakushima, July 16, 1918.

Local distribution.   Honshiu ; Shikoku ; Kinshiu ; Hokkaido.

General distribution.   Japan ; Formosa ; Corea ; China ; India ; Africa.

Subfam. SIGINÆ.

Genus *Leechia*.

Leechia South, Trans. Ent. Soc. 1901, p. 400.

South states "neuration similar to that of *Niphopyralis* Hampson, but all the wings have veins 4, 5 stalked." The genus also characterized by the veins 7, 8, 9, 10 and 11 of the forewings being stalked.

Leechia sinuosalis.

Leechia sinuosalis South, Trans. Ent. Soc. 1901, p. 400, pl. 14. f. 15.

A male taken by me at Kosugitani, Yakushima, August 14, 1918.

Local distribution.   Honshiu; Kiushiu.

General distribution.   Japan; China.

Patissa fulvosparsa.

Aporima fulvosparsa Butl. Trans. Ent. Soc. 1881, p. 591; Hmpsn. Moths Ind.
      IV. p. 44; Leech, Trans. Ent. Soc. 1901, p. 401.
Patissa tortualis Snellen, Tijd. Ent. XXXVI. p. 58, pl. 3. f. 3.

Two males and one female taken by me at Kita-tane, Tanegashima, June 10, 1919.

Local distribution.   Honshiu; Kiushiu.

General distribution.   Japan; Corea; Java; India.

Scirpophaga auriflua.

Scirpophaga auriflua Zell. Chil. et Cramb. p. 2 (1863); Hmpsn. Moths Ind.
      IV. p. 46; Leech, Trans. Ent. Soc. 1901, p. 401.
Spurima xanthogastrella Wlk. Cat. XXVII. p. 194 (1863).

A male taken by HABUTSU in Yakushima, August 1910.

Local distribution.   Honshiu; Kiushiu.

General distribution.   Japan; China; Java; Borneo; India.

Subfam. ANERASTIANÆ.

Nephopteryx semirubella.

Phalæna semirubella Scop. Ent. Carn. p. 245 (1763); Hmpsn. Moths Ind. IV.
  p. 84; Leech, Trans. Ent. Soc. 1901, p. 408.

Tinea carnella Linn. Syst. Nat. 12 ed. p. 887.

Tinea sanguinella Hübn. Summl. eur. Schmett. f. 65.

S debria icterella Rag. Nouv. Phycit. p. 18 (1888).

Laodamia semirubella var *icterella* Rag. Rom. Mém. VII. p. 416, pl. 17. f. 4.
  (1893).

  Common in Yakushima and Tanegashima.

  Local distribution.   Hokkaido; Honshiu; Kinshiu; Shikoku.

  General distribution.   Japan; Corea; China; Siberia; India; Europe.

Etiella zinckenella.

Phycis zinckenella Treit. Schmett. Eur. IX. 1. p. 201 (1832); Hmpsn. Moths
  Ind. IV. p. 108; Leech, Trans. Ent. Soc. 1901, p. 413.

Crambus subulinus Butl. A. M. N. H. (5) IV. p. 456 (1879).

  A female taken by me at Noma, Tanegashima, June 16, 1918.

  Local distribution.   Honshiu; Kinshiu.

  General distribution.   Universal.

Subfam. ENDOTRICHINÆ.

Endotricha consocia.

Doththa consocia Butl. A. M. N. H. (5) IV. p. 452 (1879); Leech, Trans. Ent.
  · Soc. 1901, p. 419.

  A male taken by me in Yakushima, July 13, 1918.

  Local distribution.   Hokkaido; Honshiu; Kinshiu.

  General distribution,   Japan; China.

Endotricha theonalis.

Pyralis theonalis Wlk. Cat. XIX. p. 900 (1859); Leech, Trans. Ent. Soc.
  1901, p. 417; Wileman, Trans. Ent. Soc. 1911, p. 368.

Pyralis(?) *thermusalis* Wlk. Cat. XIX. p. 912 (1859).

Zavia unicalis Wlk. Cat. XXXIV. p. 1257 (1865).

    A male taken by me at Nishinoomote, Tanegashima, July 23. 1918.

    Local distribution. Hokkaido; Honshiu; Kiushiu.

    General distribution. Japan; Formosa; China.

Subfam. PYRALINÆ.

Stemmatophora bicoloralis.

Endotricha bicoloralis Leech, Entom. XXII. p. 65, pl. 4. f. 17 (1889 : Hmpsn.
    Moths Ind. IV. p. 157; Leech, Trans. Ent. Soc. 1901, p. 425.

Pyralis dulciendalis Swinhoe, P. Z. S. 1889, p. 418; Hmpsn. Ill. Het. B. M.
    VIII. pl. 156. f. 13.

    Very common in Yakushima.

    Local distribution. Honshiu; Kiushiu.

    General distribution. Japan; Corea; China; India.

Herculia pelasgalis.

Pyralis pelasgalis Wlk. Cat. XVII. p. 269 (1859); Leech, Trans. Ent. Soc.
    1901, p. 427.

    Three females taken by me at Miyanoura, Yakushima, and Kaminaka,
Tanegashima, June 12, 1919.

    Local distribution. Honshiu; Kiushiu.

    General distribution. Japan; Corea; China.

Bostra marginata.

Poaphila marginata Wlk. Cat. XXXIII.. p 991 (1865); Hmpsn. Moths Ind.
    IV. p. 176; Leech, Trans. Ent. Soc. 1901, p. 431.

Palea rufescens Butl. A. M. N. H. (5) IV. p. 354.

Pyralis assamica Moore, Lep. Atk. p. 205, pl. 7. f. 5.

    A female taken by me at Nishinoomote, Tanegashima, July 26, 1918.

    Local distribution. Honshiu; Kiushiu.

    General distribution. Japan; Corea; Borneo; India.

Subfam. NYMPHULINÆ.

Cataclysta junctalis.

Cataclysta junctalis Hmpsn. Ill. Het. B. M. VIII. p. 140, pl. 155. f. 21 (1891);
Trans. Ent. Soc. 1896, p. 118.

Cataclysta blandialis (part) Hmpsn. Moths Ind. IV. p. 197 (1896).

Four females and one male taken by me at Noma, Tanegashima, July
11, 15, 1919.

Hitherto unrecorded from Japan.

Local distribution. Kiushiu (Tanegashima).

General distribution. Japan ; India.

Musotima aeclaralis.

Isopteryx aeclaralis Wlk. Cat. XVII. p. 403 (1859); Hmpsn. Ill. Het. B. M.
IX. p. 180, pl. 174. f. 24 ; Moths Ind. IV. p. 200.

A female taken by me at Miyanoura, Yakushima, July 12, 1918, and
another female taken at Noma, Tanegashima, June 15, 1919. Hitherto
unrecorded from Japan.

Local distribution. Kiushiu (Yakushima, Tanegashima).

General distribution. Japan ; India.

Bradina admixtalis.

Botys admixtalis Wlk. Cat. XVIII. p. 665 (1859); Hmpsn. Moths Ind. IV.
p. 227 ; Leech, Trans. Ent. Soc. 1901, p. 440.

Botys pruncusalis Wlk. Cat. XIX. p. 998 (1859).

Pleonectusa labidalis Led. Wien. Ent. Mon. VII. p. 426 (1863).

Pleonectusa sodalis Led. Wien. Ent. Mon. VII. p. 426 (1863).

Botys leptogastralis Wlk. Cat. XXXIV. p. 1432.

Pleonectusa pallidalis Warr. A. M. N. H. (6) XVII. p. 147 (1896).

Very common throughout Tanegashima and Yakushima.

Local distribution. Honshiu ; Kinshiu.

General distribution. Japan ; India.

Diathrausta picata.

Damaya picata Butl. Ill. Het. B.M. VII. p. 94, pl. 134. f. 17 (1889);
    Hmpsn, Moths Ind. IV. p. 234 (1896); Leech, Trans. Ent. Soc. 1901,
    p. 442.

    A male and a female taken by me at Noma, Tanegashima, July 15,
1919. The specimens have the postmedial line hardly traceable.

    Local distribution. Honshiu; Kiushiu.

    General distribution. Japan; China; India.

Piletocera sodalis.

Desmia sodalis Leech. Entom. XXII. p. 71. pl. 4. f. 6 (1889); Hmpsn.
    Trans. Ent. Soc. 1896, p. 213; Leech, Trans. Ent. Soc. 1901. p. 442.

    Five males and three females taken by me at Miyanoura and Kosugitani,
Yakushima, July 12 and 14, 1918, and a male at Noma, Tanegashima. June
15, 1919.

    Local distribution. Honshiu; Kiushiu.

General distribution. Japan; China.

Piletocera aegimiusalis.

Desmia aegimiusalis Wlk. Cat. XIX. p. 929 (1859); Hmpsn. Moths Ind. IV.
    p. 236; Leech, Trans. Ent. Soc. 1901, p. 443.

    A female taken by me at Miyanoura, Yakushima, July 12, 1918. In
the specimen the collar and the base of abdomen are concolorous with the
wings instead of being whitish. The expanse of wings measures 20 mm.

    Local distribution. Kiushiu.

    General distribution. Japan; Andamans; Borneo; Mysol; India.

Camptomastyx hisbonalis.

Botys hisbonalis Wlk. Cat. XVIII. p. 707 (1859); Hmpsn. Moths Ind. IV. p.
    239; Leech, Trans. Ent. Soc. 1901, p. 443.

Botys picalis Leech, Entom. XXII. p. 69. pl. 4. f. 15 (1889).

Diplotyla longiplpis Butl. Ill. Het. B.M. VII. p. 95, pl. 135. f. 4 (1889).

    A female taken by me each in Yakushima and Tanegashima, July 14,

1918, and June 1919. The specimen taken in Yakushima with the vein 10 of forewings separated from 8 and 9.

Local distribution. Kiushiu.

General distribution. Japan; China; Borneo; Siam; India.

Subfam. AGROTERINÆ.

Zinckenia recurvalis.

Phalaena recurvalis Fabr. Syst. Ent. p. 407 (1775); Ent. Syst. III. (2) p. 237; Zell. Lep. Caffr. p. 55; Guen. Delt. et Pyr. p. 225, pl. 8. f. 5; Wlk. Cat. XVII. p. 395.

Phalaena Pyralis fascialis Cram. Pap. Exot. IV. pl. 398. f. O (1782).

Phalaena angustalis Fabr. Mant. Ins. p. 222 (1787).

Hymenia diffescidis Hübn. Verz. p. 361

Hydrocampa albifascialis Boisd. Faun. Ent. Madag. Lep. p. 119, pl. 16. f. 1. (1834).

Two females taken by me at Miyanoura, Yakushima, and Nishinomote, Tanegashima, July 12, 26, 1918.

Local distribution. Hokkaido; Honshiu; Kiushiu.

General distribution. Japan; Formosa; China; Malay; India; Australia; Africa, etc.

Pagyda quadrilineata.

Pagyda quadrilineata Butl. Trans. Ent. Soc. 1881, p. 586; Leech, Trans. Ent. Soc. 1901, p. 452.

A female taken by me at Noma, Tanegashima, June 15, 1919.

Local distribution. Honshiu; Kiushiu.

General distribution. Japan; Corea.

Cnaphalocrocis medinalis.

Salbia medinalis Guen. Delt. et Pyr. p. 201 (1854); Hmpsn. Moths Ind. IV. p. 275; Leech, Trans. Ent. Soc. 1901, p. 452.

Botys rutilalis Wlk. Cat. XVIII. p. 665 (1859).

Botys iolealis Wlk. Cat. XVIII. p. 666 (1859).

Cnaphalocrocis jolinalis Led. Wien. Ent. Mon. VII. p. 385, pl. 12. f. 7 (1863).

Botys fasciculalis Wlk. Cat. XXXIV. p. 1431.

Botys acerrimalis Wlk. Cat. XXXIV. p. 1449.

    A female taken by me at Kumano, Tanegashima, July 14, 1919.

    Local distribution, Honshiu; Kiushiu.

    General distribution. Japan; Corea; China; Throughout Oriental and Australian regions.

Syngamia floridalis.

Syngamia floridalis Zell. K. Vet.-Ak. Handl. 1852, p. 60; Hmpsn. Moths Ind. IV. p. 280.

Glyphodes calidalis Guen. Delt. et Pyr. p. 294.

Syngamia octorialis Wlk. Cat. XVII. p. 334.

Syngamia merionealis Wlk. Cat. XVII. p. 334.

Syngamia tiphalis Wlk. Cat. XVII. p. 335.

Hyalea fulvidalis Wallengr. Wien. Ent. Mon. 1860, p. 174.

Botys witialis Feld. Reise Nov. pl. 135. f. 8.

    A male taken by me at Miyanoura, Yakushima, July 12, 1918.

    Local distribution. Kiushiu.

    General distribution. Japan; Malay; India; Africa.

Bocchoris inspersalis.

Botys inspersalis Zell. Lep. Caffr. p. 33 (1852): Led. Wien. Ent. Mon. VII. p. 434; Hmpsn. Moths Ind. IV. p. 284 (1896); Leech, Trans. Ent. Soc. 1901, p. 454.

Desmia afflictalis Guen. Delt. et Pyr. p. 190, pl. 5. f. 4 (1854).

Aediodes bootanalis Wlk. Cat. XXXIV. p. 1298 (1865).

Desmia stellaris Butl. Ill. Het. B. M. III. p. 73, pl. 58. f. 15 (1879).

    A female taken by me at Kitatane, Tanegashima, June 10, 1919.

    Local distribution. Honshiu; Kiushiu.

    General distribution. Japan; China; India; Africa.

Tyspanodes (?) *striata.*

Astura striata Butl. Ill. Het. B. M. III. p. 76, pl. 59. f. 10 (1879); Leech,
Trans. Ent. Soc. 1901, p. 456.

Common in Yakushima and Tanegashima.

Local distribution. Hokkaido; Honshiu; Kiushiu; Shikoku.

General distribution. Japan; Corea; China.

In the hindwings the veins 4 and 5 are not closely approximated, but
well separated or slightly approximated, and the veins 6 and 7 shortly stalked.
The frons is rounded instead of being flat and oblique.

Dichocrocis punctiferalis.

Astura punctiferalis Guen. Delt. et Pyr. p. 320 (1854); Hmpsn. Moths Ind.
IV. p. 307; Leech, Trans. Ent. Soc. 1901, p. 456.

A male taken at Nishinoomote, Tanegashima, July 26, 1918.

Local distribution. Honshiu; Kiushiu.

General distribution. Japan; Corea; China; Malay; India; Australia.

Phryganodes noctescens.

Charema noctescens Moore, Lep. Atk. p. 218 (1888); Hmpsn. Moths. Ind. IV.
p. 303; Leech, Trans. Ent. Soc. 1901, p. 457.

A female taken by me at Nishinoomote, Tanegashima, July 27, 1918.

Local distribution. Honshiu; Kiushiu.

General distribution. Japan; Corea; China; Java; Borneo; India.

Nocoleia poconalis.

Botys poconalis Wlk. Cat. XVIII. p. 639 (1859); Hmpsn. Moths Ind. IV. p.
313; Leech (part), Trans. Ent. Soc. 1901, p. 458.

Two females taken by me at Miyanoura, Yakushima, July 12, 1918.

Local distribution. Honshiu; Kiushiu.

General distribution. Japan; Corea; China; India; Borneo; Java;
Flores.

Nacoleia misera.

Asopia misera Butl. Ill. Het. B. M. III. p. 74, pl. 59. f. 5 (1879).
Nacoleia poeonalis Leech (part), Trans. Ent. Soc. 1901, p. 458.

A female taken by me at Nishinoomote, Tanegashima, July 26, 1918.

Local distribution. Honshiu ; Kiushiu.

Habitat. Japan.

Nacoleia tristrialis.

Botys tristrialis Brem. Lep. Ost-Sib. p. 68, pl. 4. f. 7 (1864) ; Hmpsn. Moths.
Ind. IV. p. 313 ; Leech, Trans. Ent. Soc. 1901, p. 458.

A male taken by me at Kosugitani, Yakushima, July 14, 1918.

Local distribution. Hokkaido ; Honshiu ; Kiushiu.

General distribution. Japan ; China ; Siberia ; India.

Nacoleia tampiusalis.

Botys tampiusalis Wlk. Cat. XVIII. p. 704 (1859) ; Hmpsn. Moths. Ind. IV.
p. 318 ; Leech, Trans. Ent. Soc. 1901, p. 460.
Botys ilusalis Wlk. Cat. XVIII. p. 705 (1859).
Aplomastyx minula Hmpsn. Ill. Het. B. M. VIII. p. 138, pl. 155. f. 23 (1891).

Very common in Yakushima and Tanegashima.

Local distribution. Honshiu ; Kiushiu.

General distribution. Japan ; India ; Borneo.

SWINHOE states that *ilusalis* is quite distinct from *tampiusalis*, and less
than half its size.

Goniorhynchus exemplaris.

Goniorhynchus exemplaris Hmpsn. P. Z. S. 1898, p. 705 ; Leech ; Trans. Ent.
Soc. 1901, p. 403.

Two males and females taken by me at Miyanoura, Yakushima, July 12,
1918.

Local distribution. Honshiu, Kiushiu.

Habitat. Japan.

Sylepta luctuosalis.

Hyditis luctuosalis Guen. Delt. et Pyr. p. 290 (1854); Hmpsn. Moths Ind. IV. p. 340; Leech, Trans. Ent. Soc. 1201, p. 464.

Botys arcualis Wlk. Cat. XVIII. p. 671 (1859).

Botys cosisalis Wlk. Cat. XVIII. p. 685 (1859).

Ebulea zelleri Bren. Lep. Ost.-Sib. p. 70, pl. 6. f. 12 (1864)

Coptobasis andamealis Moore, P. Z. S. 1877, p. 615, pl. 60. f. 14.

Hymenia erebina Butl. Ill. Het. B. M. II. p. 57, pl. 39. f. 1 (1878).

Very common in Yakushima.

Local distribution. Hokkaido; Honshiu; Kiushiu; Shikoku.

General distribution. Japan; Corea; China; Siberia; Borneo; India.

Sylepta aurantiacalis.

Pyralis aurantiacalis Fisch. V. Röstl. Schmett. p. 213, pl. 75. f. 3 (1843); Hmpsn. Moths. Ind. IV. p. 337; Leech. Trans. Ent. Soc. 1901, p. 465; Rebel, Cat. Lep. pal. p. 54.

Botys aurea Butl. Ill. Het. B. M. III. p. 76, pl. 59. f. 12.

Sylepta balteata Hmpsn. P. Z. S. 1898, p. 718.

A male and a female taken by me at Miyanoura, Yakushima, and at Nishinoomote, Tanegashima, July 11, 28, 1918.

Local distribution. Honshiu; Kiushiu.

General distribution. Japan; Corea; China; India; Europe.

Sylepta andrewsalis.

Pyrausta andrewsalis Wileman, Trans. Ent. Soc. 1911, p. 389, pl. 30. f. 7.

Several males and females taken by me at Kosugitani, Yakushima. In some females the inner margin of the forewings is not yellow towards base as stated in the original description, the yellow-edged antemedial line is visible only below the cell, and the double yellow spot beyond the cell is present or absent.

Local distribution. Hokkaido; Kiushiu (Yakushima).

Habitat. Japan.

Sylepta sabinusalis.

Botys sabinusalis Wlk. Cat. XVIII. p. 703 (1859); Hmpsn. Moths Ind. IV.
    p. 333; Leech, Trans. Ent. Soc. 1901, p. 466.

Notarcha butyrina Meyr. Trans. Ent. Soc. 1886, p. 260.

Notarcha dubia Hmpsn. Ill. Het. B. M. VIII. p. 136. pl. 155. f. 16.

    A male taken by me at Nishinoomote, Tanegashima, July 26, 1918.

    Local distribution.   Honshiu; Kiushiu.

    General distribution.   Japan; Corea; China; Borneo; India.

Sylepta quadrimaculalis.

Scopula quadrimaculalis Koll. Hüg. Kasch. IV. p. 492; Led. Wien. Ent.
    Mon. VII. p. 430, pl. 16. f. 12; Hmpsn. Moths Ind. IV. p. 336; Leech,
    Trans. Ent. Soc. 1901, p. 470.

    Three females taken by me at Kosugitani, Yakushima, and at Noma,
Tanegashima, July 14, 1918, June 11, 1919.

    Local distribution.   Hokkaido; Honshiu; Kiushiu.

    General distribution.   Japan; China; Borneo; India.

Margaronia telphusalis.

Glyphodes (?) *telphusalis* Wlk. Cat. XIX. p. 974 (1859); Hmpsn. Moths Ind.
    IV. p. 284.

Heterocnephes reniperalis Snell. Trans. Ent. Soc. 1890, p. 616.

Glyphodes uncinalis Pag. J. B. Nass. Ver. XXXVII. p. 273, pl. 7. f. 6 (1884).

Glypodes albilunalis Wileman, Trans. Ent. Soc. 1911, p. 381, pl. 31. f. 12.

    A female taken by me at Miyanoura, Yakushima, July 12, 1918.

    Local distribution.   Honshiu; Kiushiu.

    General distribution.   Japan; Borneo; India.

Margaronia actorionalis.

Glyphodes actorionalis Wlk. Cat. XVII. p. 498 (1859); Hmpsn. Moths. Ind.
    IV. p. 359.

Glyphodes zelleri Led. Wien. Ent. Mon. 1863, p. 478, pl. 14. f. 3.

Glyphodes conclusalis Wlk. Cat. XXXIV. p. 1351; Hmpsn. Ill. Het. B. M.
VIII. pl. 156. f. 12.

A female taken by me at Kumano, Tanegashima, June 14, 1919.

Local distribution. Honshiu (Kii); Kiushiu (Tanegashima).

General distribution. Japan; Malay; India.

Margaronia perspectalis.

Phakellura perspectalis Wlk. Cat. XVIII. p. 515 (1859); Hmpsn. Moths Ind.
IV. p. 353; Leech, Trans. Ent. Soc. 1901, p. 472.

Phacellura adscendalis Led. Wien. Ent. Mon. VII. p. 401, pl. 13. f, 17.

A male taken by me in Yakushima, July 12, 1918.

Local distribution. Hokkaido; Honshiu; Kiushiu.

General distribution. Japan; Corea; China; India.

Margaronia bipunctalis.

Glyphodes bipunctalis Leech, Entom. XXII. p. 70, pl. 3, f. 2 (1889); Trans.
Ent. Soc. 1901, p 475.

A female taken by me in Yakushima, July 1918.

Local distribution. Honshiu; Kiushiu.

Habitat. Japan.

Thliptoceras caecale.

Hapalia caecalis Swinhoe, Trans. Ent. Soc. 1890, p. 271, pl. 8. f. 18; Hmpsn.
Moths Ind. IV. p. 377; Leech, Trans. Ent. Soc. 1901, p. 477.

Thliptoceras variabils Swinhoe, Trans. Ent. Soc. 1890, p. 274.

A female taken by HABUTSU in Tanegashima, September 1910.

Local distribution. Honshiu; Kiushiu.

General distribution. Japan; India.

Diasemia accalis.

Scopula (?) *accalis* Wlk. Cat. XIX. p. 1015 (1859); Hmpsn. Moths Ind. p.
411; Leech, Trans. Ent. Soc. 1901, p. 487.

A male taken by me at Nishinoomote, Tanegashima, June 9, 1919.

Local distribution. Honshiu; Kiushiu.

General distribution.   Japan ; China ; India.

Pionea genialis.

Botys genialis Leech, Entom. XXII. p. 69, pl. 3, f. 10 (1889) ; Trans. Ent.
Soc. 1901, p. 493.

A female (exp. 18 mm.) taken by me at Nishinoomote, Tanegashima, July
28, 1918.

Local distribution.   Kiushiu.

General distribution.   Japan ; China.

Pyrausta nubilalis.

Pyralis nubilalis Hübn. Samml. eur. Schmett. Pyr. f. 94 ; Hmpsn. Moths Ind.
IV. p. 435 ; Leech, Trans. Ent. Soc. 1901, p. 503 ; Rebel, Cat. Lep. pal.
p. 65.

Pyralis silacealis Hübn. Samml. eur, Schmett. Pyr. f. 116.

Botys luplinalis Guen. Delt. et Pyr. p. 331 (1854).

Botys zealis Guen. Delt. et Pyr. p. 332 (1854).

Two males and a female taken by me at Miyanoura, Yakushima, July
12, 1918.

Local distribution.   Hokkaido ; Honshiu ; Kiushiu ; Shikoku.

General distribution.   Japan ; Corea ; China ; Siberia ; India ; Asia Minor ;
Europe.

Pyrausta fimbriata.

(Pl. III. fig. 7.)

Paralea fimbriata Swinhoe, Cat. Lep. Oxf. Univ. Mus. II. p. 523, pl. 8. f. 34
(1900).

Two males and a female taken by me at Miyanoura, Yakushima, July
12, 1918.

Hitherto unrecorded from Japan.

Local distribution.   Kiushiu (Yakushima).

General distribution.   Japan ; China.

Fam. **Orneodidæ.**

Orneodes ochracea. n. sp.

Palpi ochraceous whitish, second joint rough scaled towards extremity, thickly irrorated with fuscous, third banded with fuscous at middle. Antennæ ochraceous whitish, sparsely irrorated with fuscous towards base. Head whitish ochreous, tinged with fuscous on frons and on vertex. Thorax whitish ochreous with two fuscous transverse bands. Legs white, fore tibiæ fuscous, mid tibiæ with the basal half suffused with dark grey. Abdomen, ochreous thickly irrorated with fuscous, a dorsal white spot at the hind margin of each segment. Forewings ochreous; first segment tinged with fuscous towards base, with 4 fuscous rather large spot edged with oblique white marks, a fifth at apex: segments 2-6 crossed by two fuscous bands edged with white lines, first median, excurved and broadest on fifth segment, second subterminal, incurved at middle and on inner margin, broadest on third segment, narrowest on fifth segment; each segment with a black apical dot; cilia dark grey. Hindwings ochreous, basal area irrorated with dark fuscous; segments crossed by two more or less irregular fuscous bands as on forewings but less distinct and darker towards inner margin, each segment with two blackish spots between the bands, a black spot at end of each segment; cilia as on forewings.

Expanse, ♂ 11 mm.

A male taken by me in Tanegashima, June 10, 1919.

Fam. **Alucitidæ.**

Pselnophorus japonicus. n. sp.

(Pl. III. fig. 10.)

Head and thorax dark fuscous; palpi whitish; pectus whitish, tinged with fuscous. Abdomen above dark fuscous more or less irrorated with white, beneath white banded with fuscous. Hind tibiæ with a basal, medial, and apical dark fuscous band, tarsi white with the basal joint slightly tinged with fuscous. Wings dark fuscous. Forewings with a discoidal white lunule, an antemedial small white spot in cell, sometimes obsolete, first cleft with two

white small streaks near extremity, one at apex and another before apex on lower margin; second cleft with a white streak at apex; cilia blackish with a white spot at apex and on lower margin of first cleft, two white spots on costa before apex, and on lower margin of second cleft. Hindwings sometimes with a white spot in cell; cilia of lower margin of second cleft spotted with white near apex.

Expanse, 14–16 mm.

Three males taken by me at Noma, Tanegashima. June 11, 14, 1919.

Fam. **Simæthidæ.**

Simaethis yakushimensis. n. sp.

(Pl. III. fig. 8.)

♀. Head orange fulvous sprinkled with whitish. Palpi white, second and terminal joints with basal and subapical fulvous bands. Antennæ white ringed with black. Thorax orange fulvous, posteriorly mixed with dark fuscous and slightly whitish sprinkled. Abdomen dark fuscous irrorated with orange ochreous. Posterior tibiæ whitish ochreous banded with dark fuscous, tarsi whitish, first and second joints with subapical fulvous rings, two apical joints dark fuscous. Forewings triangular, costa moderately arched, apex obtuse, termen almost straight, somewhat oblique; orange ochreous irrorated with whitish; antemedial band slightly sinuous, ferruginous brown mixed with black, followed by a posteriorly undefined shade of whitish irroration; postmedial anteriorly somewhat ill-defined band strongly bent outwards below costa, bidentate at middle, broken inwards below it and minutely bidentate; defined by whitish on its outer side; subterminal band black, interrupted at middle; terminal line black; cilia red-brown mixed with dark fuscous at apex, at middle and at tornus. Hindwings dark fuscous; subterminal line red-brown, only distinct towards tornus; terminal line black; cilia red-brown with the tips whitish.

Expanse 12 mm.

A female taken by me at Miyanoura, Yakushima, July 12, 1918.

Simaethis(?) *albifascialis*. n. sp.

(Pl. III. fig. 9.)

♂. Head and thorax fulvous sprinkled with whitish. Palpi white, second joint with basal and subapical fulvous brown bands, terminal joint mixed with fulvous brown. Antennæ white ringed with black. Abdomen dark fuscous tinged with fulvous. Posterior tibiæ fulvous brown irrorated with white, tarsi white, first and second joints with subapical fulvous brown rings, two apical joints fulvous brown. Forewings triangular, costa moderately arched, apex rather obtuse, termen slightly sinuous; fuscous brown tinged with ferruginous especially on terminal area; basal area orange ochreous, defined on each side by a shade of white irroration; a white streak on discocellulars; postmedial line white defined by dark fuscous on inner side below middle, double towards costa, excurved at middle, then incurved and slightly waved; cilia red-brown, tips whitish, with a blackish line at base, tinged with blackish at apex, at middle and at tornus. Hindwings dark fuscous, traces of subterminal line near tornus; cilia red-brown, tips whitish, blackish line at base.

Expanse 13 mm.

A male taken by me at Nishinoomote, Tanegashima, June 10, 1919.

Another male taken at Miyanoura, Yakushima, July 12, 1918.

Fam. **Plutellidæ**.

Plutella maculipennis.

N. g. *maculipennis* Curtis, Guide, p. 186 (1831).

Cerostoma maculipennis Curtis, Brit. Ent. pl. 420 (explanation p. 2) (1832); Steph. Ill. Brit. Ent. Haust. IV. p. 342; Wals. and Durr. Ent. Mon. Mag. 1897, p. 173; Rebel, Cat. Lep. pal. p. 137.

Cerostoma annulatellus Wood, Ind. Ent. pl. 49, 1547 (1839).

Plutella cruciferarum Zell. Stett. Ent. Zeit. 1843, p. 281.

Plutella xylostella Staud. et Wocke, Cat. p. 281 (1871).

A male taken by me at Noma, Tanegashima, June 14, 1914.

Local distribution. Hokkaido; Honshiu; Kiushiu.

General distribution. Japan; Siberia; Europe.

In order to facilitate the general consideration of the faunal feature of the two islands I append here the following table illustrating the geographical distribution of respective species.

Localities. / Species	Formosa.	Loochoo.	Yakushima.	Tanegashima.	Kiushiu.	Shikoku.	Honshiu.	Hokkaido.	Other localities. Palaearctic.	Oriental.
Nola trilinea n sp.				×						
Lexis immaculata Butl.	×		×				×?		×	×
Ilema affineola Brem.										
Asura intermedia n. sp.			×							
Diacrisia subcarnea Wlk.	×	×	×		×		×		×	
Utetheisa pulchella Linn	×	×		·	×		×		×	×
Cirphis flavostigma Brem.	×		×		×		×	×	×	×
Delta intermedia Brem.				×	×		×		×	×
Phyllophila obliterata Rmbr			×		×		×		×	
Lithacodia signifera Wlk.			×		×		×		×	×
Naranga aenescens Moore.	×			×	×		×		×	
Phlogophora sinuosa Moore			×				×			×
Cotocala pregnax Wlk.				×	×		×	×	×	
Erebus crepuscularis Linn.		×	×		×	×	×	×	×	×
Metopta rectifasciata Mén.	×		×	×	×	×	×	×	×	
Ophisma gravata Guen.		×		×					×	×
Parallelia curvata Leech.		×		×			×		×	
Chalciope hyppasia Cram.	×	×	×						×	×
Mocis undata Fabr.	×		×		×		×		×	×
Mocis anneta Butl.			×		×	×	×	×	×	
Phytometra daubei Boisd.			×	×					×	×
Thermesia ussuriensis Brem			×		×	×	×	×	×	
Hypocala subsatura Guen.			×				×		×	×
Oraesia emarginata Fabr,			×		×		×		×	×
Oraesia excavata Butl.				×	×		×		×	
Plusiodonta caelonota Koll.		×		×	×		×		×	×
Pseudaglossa pryeri Butl.			×		×		×			
Edessena hamada Feld.				×	×		×		×	
Dichromia trigonalis Guen,	×		×	×	×		×		×	×
Porthesia pulverea Leech.		×	×	×	×		· ×		×	
Porthetria dispar Linn.			×						×	
Porthetria nobunaga Nagano			×				×			

Localities. Species.	Formosa	Loochoo	Yakushima	Tanegashima	Kiushiu	Shikoku	Honshiu	Okkaido	Other localities Palæarctic	Oriental
Nyctemera mundipicta Wlk.			×							×
Nyctemera plagifera Wlk.	×	×	×						×	×
Nyctemera coenis Cram.	×	×	×	×						×
Herse convolvuli Linn.	×?	×	×		×	×	×	×	×	×
Cephonodes xanthus Roths et Jord.		×		×						
Gurelca masuriensis Butl.	×			×					×	×
Gurelca hyas Wlk.	×		×	×	×		×		×	×
Macroglossum pyrrhosticta Butl.		×	×	×	×					×
Theretra oldenlandiae Fabr.			×	×	×	×	×	×	×	×
Theretra silhetensis Wlk.	×	×	×	×	×				×	×
Eamesa straminea Moore.				×	×		×		×	
Urapteryx subpunctaria Leech.				×	×					
Thinopteryx crocoptera Koll.			×		×		×		×	×
Synegia esther Butl.			×		×		×		×	
Synegia hadassa Butl.			×		×		×		×	
Scionomia mendica Butl.			×				×	×	×	
Zethenia rufescentaria Motsch.			×		×		×	×	×	
Heterolocha laminaria H.–Sch.				×			×	×	×	
Corymica specularia Moore			×				×		×	×
Spilopera gracilis Butl.			×				×		×	×
Rhynchobapta flaviceps Butl.					×	×		×	×	×
Macaria pluviata F.					×	×				
Tephrina semilutata Led.			×			×	×	×	×	
Arichanna jaguararia Guen			×						×	
Abraxas miranda Butl.			×						×	
Asthena erectaria Leech.			×				×	×		
Cidaria saturata Guen.			×						×	×
Photoscotosia atrostrigata Brem.			×						×	
Scopula steganioides Butl.			×			×		×	×	

Species. / Localities.	Formosa.	Lo choo.	Yakushima.	Tanegashima.	Kinshin.	Shikoku.	Honshin.	Hokkaido.	Palæ-arctic.	Oriental.
Scopula lactea Butl.				×	×		×		×	
Scopula ignobilis Warr.			×		×		×		×	
Scopula satsumaria Leech.			×		×					
Scopula hanna Butl.			×	×			×		×	
Scopula apicipunctata Christ.			×		×				×	
Scopula coniaria Prout;			×		×		×			
Scopula plumbearia Leech				×	×					
Timandra amata Linn.			×		×	×	×	×	×	×
Chloromachia infracta Wileman.			×				×			
Gelasma albistrigata Warr			×		×		×			
Doratoptera virescens n. sp			×	×						
Epiplema moza Butl.				×	×		×			×
Epiplema cretacea Butl.				×	×		×			
Mirea inornata Wlk.			×		×		×	×	×	×
Microleon longipalpis Butl.			×		×		×		×	
Euploea tytia Gray.	×	×	×		×	×	×	×	×	×
Ypthima argus Butl.			×	×	×	×	×	×	×	
Neope goschkewitschii Men.			×	×	×	×	×	×		
Melanitis phedisma Cram.	×	×		×	×	×	×		×	×
Melanitis leda Linn.	×			×	×	×	×		×	×
Mycalesis gotama Moore.		×	×	×	×	×	×		×	
Dichorragia nesimachus Boisd.	×	×	×	×	×	×	×		×	×
Cyrestis thyodamas Boisd.	×	×	×	×	×	×	×		×	×
Neptis hylas Linn.	×	×		×	×	×	×	×	×	×
Junonia orithya Linn.	×	×	×	×	×				×	×
Junonia almana Linn.	×	×	×	×					×	×
Pyrameis cardui Linn.	×	×	×	×	×	×	×	×	×	×
Vanessa canace Johans.	×	×	×	×	×	×	×	×	×	×
Argynnis nerippe Feld.			×	×	×	×	×	×	×	
Argynnis sagana Doubl.			×	×	×	×	×	×	×	
Argynnis hyperbius Johans.	×	×	×	×	×	×	×		×	×
Hebomoia glaucippe Linn.	×	×	×	×					×	×
Pieris rapae Linn.			×	×	×	×	×	×	×	

Species.	Formosa.	Loochoo.	Yakushima.	Tanegashima.	Kiushiu.	Shikoku.	Ho Shiu.	Hokk id.	Palæarctic.	Oriental.
Pieris melete Men.			×	×	×	×	×	×		
Anthocharis scolymus Butl.			×		×	×	×			
Eurema laeta Boisd.	×	×	×		×	×	×			
Eurema hecabe Linn.	×	×	×	×	×	×	×			
Colias hyale Linn.	×	×	×	×	×	×	×	×	×	
Arhopala japonica Murray	×	×	×	×	×	×	×		×	
Arhopala bazalus Hew.			×	×	×	×	×			×
Curetis acuta Moore.			×	×	×	×			×	×
Polyommatus boeticus Linn.	×	×	×	×	×	×			×	×
Nacaduba atrata Horsfield.	×	×	×	×						×
Zizera maha Koll.	×	×	×	×	×	×	×		×	×
Everes argiades Pallas.	×	×	×	×	×	×	×	×	×	×
Cyaniris argiolus Linn.	×	×	×	×	×	×	×	×	×	×
Taraka hamada Druce.				×	×	×	×		×	×
Libythea celtis Fuessly.			×	×	×	×	×	×	×	×
Equs alcinous Klug.	×	×	×	×	×	×	×		×	
Eques protenor Cram.	×	×	×	×	×	×	×			×
Eques memnon Linn.	×	×	×	×	×	×			×	×
Eques bianor Cram.	×	×	×	×	×	×	×	×	×	×
Eques helenus Linn.	×	×	×	×	×	×	×		×	×
Eques xuthus Linn.	×	×	×	×	×	×	×	×	×	×
Eques machaon Linn.			×	×	×	×	×	×	×	×
Eques sarpedon Linn.	×	×	×	×	×	×	×	×	×	×
Rhopalocampta benjamini Guér.	×	×	×	×	×	×	×	×	×	×
Parnara mathias Fabr	×	×	×	×	×	×	×			×
Padraona flava Murray.			×		×	×	×	×		
Notocrypta curvifascia Feld	×	×	×	×	×				×	
Procris tristis Brem.					×		×		×	
Heterusia aelea Linn.		×		×	×		×		×	×
Erasmia pulchella Hope		×	×			×			×	×
Callidula formosana Wileman.	×			×	×					
Derua phasma Butl.			×		×		×			
Lamoria inostentalis Wlk.	×		×		×		×	×	×	×
Crambus lipbogrammus Zell.			×		×		×		×	

Species. \ localities.	Formosa.	Loochoo.	Yakushima.	Tanegoshima.	Kiushiu.	Shikoku.	Hu shiu.	Hokkaido.	Other localities. Palæarctic.	Oriental.
Crambus argyrophorus Butl.			×		×		×		×	×
Ancylolomia chrysographella Koll.	×		×		×	×	×	×	×	×
Leechia sinuosalis South.			×				×		×	
Patissa fulvosparsa Butl.				×	×		×		×	×
Sciryophaga aurifiua Zell.			×		×		×		×	×
Nephopteryx semirubella Scop.			×	×	×	×	×	×	×	×
Etiella zinckenella Treit.				×	×		×		×	×
Endotricha consocia Butl.			×		×		×	×	×	
Endotricha theonalis Wlk.	×			×	×		×	×	×	
Stemmatophora bicoloralis Leech			×				×		×	×
Herculia pelasgalis Wlk.			×	×	×		×		×	
Bostra marginata Wlk.				×	×		×		×	×
Cataclysta junctalis Hmpsn.				×						×
Musotima acclaralis Wlk.			×	×						×
Bradina admixtalis Wlk.			×	×	×		×			×
Diathrausta picata Butl.				×	×		×		×	×
Piletocera sodalis Leech.			×	×	×		×		×	
Piletocera aegiminsalis Wlk			×		×					×
Camptomastyx hisbonalis Wlk.			×	×	×				×	×
Zinckenia recurvalis Fabr.	×		×	×	×		×	×	×	×
Pagyda quadrilineata Butl				×	×		×		×	
Cnaphalocrocis medinalis Guen.				×	×		×		×	×
Syngamia floridalis Zell.			×							×
Bocchoris inspersalis Zell.				×	×		×		×	×
Tyspanodes(?) striata Butl.			×	×	×	×	×	×	×	
Dichocrocis punctiferalis Guen.				×	×		×		×	×
Phryganodes noctescens Moore.				×	×		×		×	×
Nacoleia pæonalis Wlk.			×		×		×		×	×
Nacoleia misera Butl.				×	×		×			

Species. Localities.	Formosa	Loochoo.	Yakushima	Tanegashima	Kiushiu.	Shikoku.	Honshiu	Hokkaido.	Other localities. Palae-arctic.	Orien-tal.
Nacoleia tristrialis Brem.			×		×		×	×	×	×
Nacoleia tampiusalis Wlk.			×	×			×			×
Goniorhynchus exemplaris Hmpsn.			×				×			
Sylepta luctuosalis Guen			×		×	×	×	×	×	×
Sylepta aurantiacalis Fisch.			×	×	×		×		×	×
Sylepta andrewsalis Wileman.			×					×		
Sylepta albimusalis Wlk.				×	×		×		×	×
Sylepta quadrimaculalis Koll.			×		×		×	×	×	×
Margaronia telphusalis Wlk.			×		×		×			×
Margaronia actorionalis Wlk				×			×			×
Margaronia perspectalis Wlk.			×		×		×	×	×	×
Margaronia bipunctalis Leech.			×		×		×			
Thliptoceras cascale Swinhoe.				×			× ?			×
Diasemia accalis Wlk.				×	×		×		×	×
Pionea genialis Leech.				×	×				×	
Pyrausta nubilalis Hübn.			×		×	×	×	×	×	×
Pyrausta fimbriata Swinhoe.			×						×	
Orneodes ochraea n. sp.			×	×						
Pselnophorus japonicus n sp.				×						
Simaethis yakusimensis n. sp.			×							
Simaethis (?) albifascialis n sp.			×							
Plutella maculipennis Curtis.				×	×	×	×	×	×	

EXPLANATION OF PLATE III.

Fig. 1.   *Nola trilinea* n. sp. ♂. ×2.

Fig. 2.   *Asura intermedia* n. sp. ♂. ×2.

Fig. 3.   *Porthetria dispar* Linn. ♂. ×1.

Fig. 4.   *Doratoptera*(?) *virescens* n. sp. ♀. ×1.

Fig. 5.   *Neope goschkevitschii* Men. ♂. Under-side of hindwing. ×1.

Fig. 6.   *Callidula formosana* Wileman. ♀. ×1.

Fig. 7.   *Pyrausta fimbriata* Swinhoe. ♂. ×1·5.

Fig. 8.   *Simaethis yakushimensis* n. sp. ♂. ×2.

Fig. 9.   *Simaethis*(?) *albifascialis* n. sp. ♂. ×2.

Fig. 10. *Pselnophorus japonicus* n. sp. ♂. ×3.

Plate III.

The Spermatogenesis of Domestic Mammals.

III. The Spermatogenesis of the Mouse and of the Rabbit.

By

Kiyoshi Masui.

(From the Laboratory for Agricultural Zoology, Director: Professor C. Ishikawa.)

With Plates IV-X and one Text-Figure.

The chromosomes are now generally proved to occur in pairs both in germ cells as well as in somatic cells. In mammals, however, owing to their great number, it is very difficult to determine their relation accurately, and the results of the investigations obtained by various workers, differ so greatly, that renewed studies are always to be welcomed, even in one and the same animals.

It is for this reason, that the present investigation was undertaken, the original object of which was chiefly the study of the chromosomes, but in the course of the investigation it was found necessary to extend the researches to the cytoplasmic structures as well. The result was the present paper which deals with the entire spermatogenesis of the mouse and of the rabbit.

The author has prepared the present paper under the direction of Professor Chiyomatsu Ishikawa to whom he wishes to express his hearty thanks for the painstaking care and sympathy given him throughout the course of this study.

Materials and Methods.

The materials on which this study is based, consist of the testes of piebald mice at different ages and those of young rabbits.

As is already known, it is difficult to obtain good results in the fixation of chromosomes in mammals. In materials which have been insufficiently prepared, the chromosomes are usually so closely massed, that it is impossible to obtain any results which can be used for cytological study. Consequently, as HANCE ('17 b) stated, it is quite true that most of the published cytological works on mammals are not reliable and should be carefully repeated.

For the fixation, therefore, several fixatives were used, namely, a modification of HANCE's method, FLEMMING's mixture, BOUIN's fluid, sublimate acetic and CHAMPY's fluid, but the first method gave the most satisfactory results.

The method of fixation used chiefly in this study is as follows:—1. The material used must be absolutely fresh and cut into very small pieces. 2. These are put immediately into FLEMMING's solution (weak) to which a little urea is added; in this the tissues remain from twenty to twenty four hours. 3. The temperature of the fixatives is about 15 degrees Centigrade. 4. Sections are bleached for from five to twenty hours in hydrogen peroxide.

For the fixation of the mammalian chromosomes HANCE ('17a, b)[1] obtained some excellent results with FLEMMING's cold strong solution which is cooled to about four degrees Centigrade; but my experience has shown that FLEMMING's fluid, either strong or week, kept at about fifteen degrees Centigrade is more preferable than the cold solution.

For the study of the chromosomes the sections were stained with HEIDENHAIN's iron-haematoxylin, and for the mitochondria also the same stain was used, though the preparations were fixed in this case with CHAMPY's fluid. The mitochondria can, however, be also differentiated in the preparation fixed with FLEMMING's strong solution to which a few drops of acetic acid are added. As control AUERBACH's method (methyl-green and acid-fuchsin) was frequently used. This method has been found most useful as a differential stain for chromatin and nucleoli.

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1. His explanation on the action of the cold FLEMMING's solution is as follows:—" It seems more probable that the explanation for the success of the cold fixation may lie in the suppression of metabolic activities when the preservation of the living structures until the fluid is able to penetrate and fix them permanently."

Observations.

I.   THE SPERMATOGONIA.

A.   The spermatogonia in the mouse.

As I have already described in cattle, in the testes of mature animals several sizes of spermatogonial cells can be distinguished (Figs. 4, 14). This difference in size seems to indicate the generations of the spermatogonia, the larger cells being earlier in generation than the smaller ones. It is, however, a difficult matter to determine accurately the number of generations of the spermatogonia.

The resting nucleus of every spermatogonial cell usually contains one nucleolus and several chromatin masses which usually lie on the nuclear membrane and on the linin threads (Figs. 126, 127). The nucleolus gives an appearance of granular construction, since a small amount of chromatin granules are gathered on the surface of it (Figs. 126, 127). Thus it is difficult to distinguish the nucleolus in the preparations stained with iron-haematoxylin (Figs. 1, 2), while this can clearly be seen in those stained with AUERBACH's method (Fig. 127).

The nucleolus gradually disappears in the prophase, leaving a plastin remnant behind; thus it is clear that there is no connection between this body and the sex-chromosomes which are found in the prophase of the first reduction division. The chromatin granules later begin to arrange themselves along short threads which correspond to the chromatin spiremes in other animals (Fig. 2). The chromatin threads now become gradually denser and thicker until the granular appearance is entirely lost to view (Fig. 3). As stated, above, the nucleolus usually disappears at the late prophase but it remains sometimes among the chromosomes in the early metaphase (Fig. 127). This, however, can not be recognized, when the chromosomes are arranged radially around the central space in the metaphase.

As the mitotic figures are rare in mammalian tissues compared with those of the lower animals, in the determination of the number of chromosomes the method of using thick sections is, in my experience, preferable to the smear method. As Montgomery ('10) stated, it is true that the difficulty in determining the number of chromosomes increases in geometrical ratio with

the increas of theire number. Owing to this fact, for the determination of the number of chromosomes only those cells were selected which were clearly recognized as being uncut, and in which the chromosomes were so distinctly separated from each other that the count could be made easily and accurately (Figs. 4, 5).

Nearly all the cells studied contain forty chromosomes. Details as to the number of chromosomes are given in the following table.

TABLE I. Showing number of chromosomes.

In determining the number, every chromosome was carefully drawn with the aid of a camera-lucida at the magnification 2000 diameters. In order to avoid miscounting the drawing was carefully compared with the chromosomes of the section under the microscope.

Thickness of sections.	10μ		5μ	
Number of chromosomes.	40	39	55	total.
Number of cases.	21	1	2	24

As shown in the above table, among the 22 thick sections only one cell contains thirty nine chromosomes. This difference in number, however, is probably due to miscounting.

From the above, it is evident that the chromosomes of the male germ cell of the mouse are constantly forty in number. The chromosomes in every spermatogonial cell vary considerably in size and form, and usually assume a somewhat curved rod- or straight rod-shape. When the chromosomes are arranged according to size and form, it is found that pairs exist among them, although they form a series which falls gradually from the largest to the smallest (Figs. 9–12). The following table and the text figure show this relation clearly.

TABLE II. Representing area of spermatogonial chromosomes
at a magnification of 32000 diameters.

Method of measurement :—A definite number of homogeneous papers (ten pieces of paper to each chromosome) which have the same size and form as each magnified chromosome and a standard area of the same paper were accurately weighed with a balance. From a comparison between the weight of the former and that of the latter, the area of each chromosome was calculated.

Chromosomes	Area in sq. mm	
	I	II
1	3 9,7	409,7
2	388,2	153,0
3	316,3	345,0
4	597,1	313,7
5	258,7	310,2
6	250,0	298,0
7	245,0	285,0
8	247,6	283,8
9	244,8	276,2
10	238,8	275,1
11	234,2	272,6
12	229,0	271,7
13	228,5	259,7
14	225,7	258,5
15	222,0	255,7
16	224,5	247,5
17	213,9	245,9
18	2 2,6	231,3
19	205,2	233,5
20	199,3	229,8
21	196,0	228,9
22	194,6	225,0
23	193,8	221,7
24	193,3	218,6
25	191,0	211,9
26	187,3	211,1
27	186,0	209,4
28	185,5	201,3
29	181,2	199,9
30	175,8	197,3
31	175,0	194,6
32	173,8	192,5
33	173,7	184,2
34	171,7	183,8
35	155,5	179,2
36	117,4	177,6
37	145,8	171,0
38	114,8	162,3
39	120,0	150,0
40	107,6	129,3
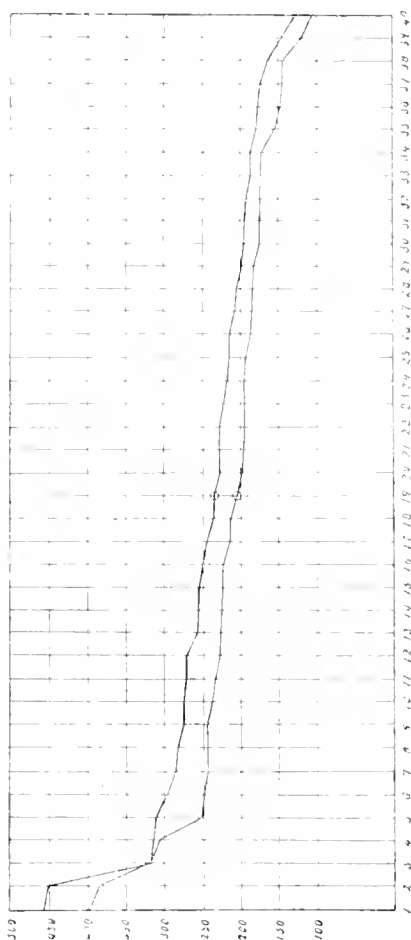
Text-fig. 1. Curves representing size relation of chromosomes.

The figures on the axis of ordinates represent size of chromosomes in sq. mm., while these along the base line are the number of chromosomes arranged according to size. The upper curve represents the size of chromosomes of Fig. 10, and the lower one that of Fig. 9.

Details of the chromosomes will be discussed later on in the considerations, pp. 234.

The chromosomes become arranged in the equatorial plate with their long axes coinciding with the latter (Fig. 7). Every chromosome now simultaneously divides into two portions along the longitudinal split, no special chromosomes with different behavior being seen among them (Figs. 8, 14). At the anaphase U- or V-shaped chromosomes which are usually observed in other animals are not produced, they assume simple rod-shap (Fig. 14).

As the spindles can not clearly be seen, it is difficult to determine directly the point of attachment of the spindle fiber. It is, however, conceivable that, if the spindle fiber attaches to the end of a chromosome, the daughter chromosomes in the anaphase must assume straight rod-shape. For this reason it seems certain that in the mouse the spindle fibers must attach to the ends of the chromosomes. ALLEN ('18) also proposed the same view in the rat, where he says: "It will be of interest to learn if it is characteristic of rodents or peculiar to the rat."

In the preparation stained with AUERBACH's method a cytoplasmic mass can usually be found in close contact to the nuclear wall, while in HEIDENHAIN's method nothing can be seen in the cytoplasm (Fig. 127). Although this mass is not so conspicuous as the idiozome in the spermatocyte, its appearance and its situation correspond almost exactly with those of the latter cells, so that I do not hesitate to identify it with the same. DUESBERG ('08) and ALLEN ('18) have not found the idiozome in the spermatogonia of the rat.

The mitochondrial granules appear in the cytoplasm, being scattered throughout the latter (Fig. 6). The amount seems to be the same as those of the young spermatocyte. In the metaphase they remain undivided and lie outside the spindle (Fig. 6). After the cell is divided into two the mitochondrial granules seem to be equally distributed in the cytoplasm of the daughter cells. The size of the granules appears to be smaller than that in the prophase of the first reduction division.

B. The spermatogonia in the rabbit.

As in the mouse, we can distinguish several kinds of spermatogonial cells which are probably of different generations (Figs. 85-87). The resting nuclei of the spermatogonial cells usually contain many chromatin masses (karyosomes) and several nucleoli which can clearly be seen in the sections stained with AUERBACH's method (Fig. 145).

During the early prophase many chromatin masses appear which gradually elongate and form the fine chromatin spiremes (Figs. 85, 86). Soon after the spiremes become thicker and are convoluted throughout the nucleus (Figs. 85, 86). At this stage nucleoli can not be seen at all (Fig. 86). In

the late prophase many long and variously curved chromosomes appear
which are entangled with each other (Fig. 86). In the metaphase it is
difficult to make out every chromosome, for the long, curved chromosomes
overlap each other, notwithstanding the perfect separation of the individual
ones (Fig. 87).

It has been found that the number of chromosomes is not constant but is
considerably variable (Figs 87–91). For counting the chromosomes only those
cells were selected which were clearly found to be meat and in which the
chromosomes were well separated (Figs. 87–91). It is therefore clear that
the variation of the number of chromosomes is not caused by the use of
poorly prepared materials. The seventeen cells studied in this connection
fall into the groups :—

TABLE III, Showing variation in the number of chromosomes.

Thickness of sections.	8_μ						
Number of chromosomes.	41	47	48	49	51	54	Total
Number of cases.	1	6	2	3	2	3	17

As in the mouse, the chromosomes vary considerably in size and form
(Figs. 87, 88). The larger chromosomes are considerably long and variously
curved, while the smaller ones appear as round bodies (Figs. 87, 89). Some
larger ones are strongly curved and sometimes the transverse constrictions
can be seen at their ends (Figs. 87-91). It is remarkable that in those
cells which contain a large number of the chromosomes, the smaller ones
increase in number, while in those having forty eight chromosomes only
four smaller ones can be seen (Figs. 89–91). From the above facts it is
conceivable that this difference in the number of chromosomes is probably
due to the influence of the fixatives.

The arrangement and the dividing method of the chromosomes are equal
to those of the mouse (Figs. 92-95). As all the chromosomes assume simply
the straight rod-shape in the anaphase, it seems most probable that the

attachment of the spindle fiber is terminal, although as in the mouse the point of attachment can not be seen (Figs. 92, 94).

In the resting spermatogonia the idiozome can clearly be seen as a long ellipsoid and is situated constantly in close contact to the nuclear wall (Fig. 145).

The mitochondrial granules appear abundantly in the cytoplasm. Their size and their behavior are entirely the same as those of the mouse (Fig. 93).

II. THE GROWTH PERIOD OF THE SPERMATOCYTE.

A. The growth period of the spermatocyte in the mouse.

In the final telophase of the spermatogonia the chromosomes break up into a confused net-like structure, and for a short time the outline of the individual chromosome can not be distinguished (Fig. 129). Soon after many chromatin masses appear, connected with fine threads (Fig. 15). The number of the chromatin masses is almost equal to that of the spermatogonial chromosomes.

The pre-synaptic stage:— At the beginning of this stage the irregular chromatin masses which appeared in the previous stage begin to elongate and finally become the chromatin threads which are comparable to those of cattle, but they are very short and appear as irregular chromatin rods (Fig. 16). Even though the number of the chromatin threads can not be exactly counted in this stage, it is clearly shown that their number is not far from that of the spermatogonial chromosomes (Fig. 16). In the preparations stained with AUERBACH's method, all the chromatin threads are stained intensely with methyl-green, and no nucleolus is found in any part of the nucleus (Figs. 129, 130).

In this stage the mitochondrial granules appear in small number in the cytoplasm (Fig. 16).

The synaptic stage:—After the brief duration of the pre-synaptic stage the chromatin threads soon begin to converge towards one side of the nucleus, leaving a clear space on the other side (Figs. 17, 130). But the tendency of the polarization of the chromatin threads is not so conspicuous as that

of the horse and of cattle. From an accurate observation, it is most probable that this slight polar aggregation of the chromatin threads is to be looked upon as the synizesis which corresponds to that of the other animals.

DUESBERG ('08) denied the occurence of synizesis in the rat. Recently ALLEN ('18) found a slight aggregation of the chromatin threads in this animal, but his view is different from mine. He says : – "A very slight polar aggregation may occur during this period but no synizesis has been observed with any method of fixation." JORDAN ('14) rarely found the synizesis occuring in the mouse, he says : "This is tentatively interpreted as synapsis (polarized amphitène). If the nucleus is normal, as it appears to be, the paired threads unmistakably indicate synapsis."

As is the case in the horse and cattle, in this stage the nuclear wall expands rapidly and soon apparently disintegrates (Fig. 130). During this stage the parallel arrangement of the spiremes can not be seen at all (Figs. 16–18). With AUERBACH's method the spiremes take the same colour as in the previous stage (Fig. 130).

Most of the mitochondrial granules are usually grouped near the pole of nucleus where the chromatin threads converge, but none of them attach to the nuclear wall (Fig. 16).

Neither the nucleolus nor the idiozome can be seen during this stage (Fig. 130).

The post-synaptic stage :—In the stage immediately following the synaptic stage the chromatin threads gradually spread throughout the nucleus, becoming more loosely situated (Figs. 18, 19). At the beginning of this stage some spiremes appear to form an end-to-end arrangement which is regarded as an indication of telosynapsis (Figs. 17, 18). In any case it is quite certain that in this stage the spiremes appear about half the original number, but they do not increase in thickness, retaining their original form (Figs. 17, 18). From this fact it is conceivable that the conjugation of chromosomes must have taken place during the previous stage (synaptic stage). Later on the chromatin threads elongate more and more until they resemble as those of the horse and cattle, while the outline of the nucleus becomes spherical and more clearly defined (Fgs. 18, 19, 131). With AUERBACH's method all the

spiremes of this stage are still stained deeply with methyl-green (Fig. 131).

At the end of this stage a nucleolus appears, usually situated close to the nuclear wall (Figs. 131, 132). It is stained both with fuchsin and methyl-green at the same time with AUERBACH's method, while with iron-haematoxylin it takes the chromatin dye (Figs. 19, 131). As the nucleolus is small in the beginning of this stage, it is difficult to distinguish it in the sections stained with iron-haematoxylin (Fig. 18). The nucleolus grows rapidly, increasing the staining capacity for acid-fuchsin, while the bulk of the cell gradually increases and the movement of the chromatin spiremes is carried out further until they fill up the nucleus throughly (Figs. 19, 20). The longitudinal splitting of chromosomes could not be observed in this stage (Figs. 18-20).

The early prophase :—With the growth of the nucleolus the chromatin threads[1] become faintly stained with iron-haematoxylin by which they show granular appearance, while with AUERBACH's method they begin to stain both with methyl-green and acid-fuchsin at the same time (Figs. 21-23, 134). As will be shown in the subsequent chapter, it seems more probable that this change of staining capacity is due to the chemical change connected with the growth of the chromosomes. With the growth of the cell this change of the staining capacity proceeds more and more until it reaches its maximum in the late prophase where the cells attain the greatest zise (Figs. 25, 27, 134).

In this stage, beside the nucleolus, two chromatin masses appear, one of which is larger than the other (Figs. 22-24). They are stained in the same manner as the ordinary chromosomes both with iron-haematoxylin and with AUERBACH's method, a fact which induces one to think that these bodies may be XY-chromosomes which exist in this stage as the chromosome nucleoli.

The nucleolus grows rapidly till it finally attains its maximum size at the end of this stage (Figs. 23-25). At the beginning of this stage the idiozome can clearly be seen, usually situated in close contact with the the nuclear membrane (Figs. 132-134).

1. This stage probably corresponds to the diffuse or confused period described by WILSON ('12). In some insects the diplotene-nuclei undergo remarkable transformation in which double threads completely disappear from view, giving rise to a diffuse, lightly staining net-like nuclei.

At about the same time the chromatoid body makes its appearance as a round body near the nuclear wall, being deeply stained with acid dyes and iron-hæmatoxylin (Figs. 21, 24). The mitochondrial granules appear abundantly in the cytoplasm, being scattered throughout the cell body. The granules are larger than those of the spermatogonia or the early spermatocyte (Fig. 26).

The late prophase:—The nuclei now undergo a remarkable transformation, characteristic in many animals, in the course of which the spiremes become more distinct and begin to shorten (Figs. 28, 29). Later on the spiremes shorten more and more until they assume long and curved rod-shape, and at the same time their staining capacity begins to increases rapidly (Figs. 30, 31, 136). Soon after various bivalent chromosomes appear which are characteristic in the mouse (Figs. 32, 33, 35). According to their characteristic form they are divided into the following two different types, namely : 1. The first type is the single ring which is formed by the union of two ends of the curved chromosomes. 2. The second type is the bivalent rod which consists of two short chromosomes. The first type can be seen only in large chromosomes, while the smaller ones belong to the second type. It is difficult to determine accurately in what manner the rings are formed. But from direct observation it seems most probable that they are formed not by separation of the longitudinal splitting which sometimes appears at the beginning of this stage in the preparation fixed with Champy's method.

When the nuclear membrane begins to disintegrate the chromosomes shorten progressively until they assume short rod-shape (Figs. 34–36).

The number of the bivalent chromosomes is obviously half of the diploid number.

At this stage the XY-chromosomes can not be identified. The absence of these chromosomes is probably due to the fact that in this stage they are united to form a bivalent chromosome.

Owing to its small size, in this stage, the nucleolus is not distinguishable with ordinary dyes (iron-hæmatoxylin), whereas with AUERBACH's method it can clearly be made out (Figs. 136, 137). At the beginning of this stage this body begins to disintegrate, leaving a small amount of chromatins behind, which is probably used up in the formation of the chromosomes (Figs. 135,

136). Soon after this body gradually diminishes in size, but being deeply stained with acid-fuchsin, it can usually be seen until the time of the disappearance of the nuclear wall (Fig. 138. When the nuclear membrane begins to disintegrate, the nucleolus except in some rare cases, can not be seen (Figs. 37, 38).

The mitochondrial granules, are now considerably increased in number as compared with previous stages (Fig. 26. At the late prophase when the nuclear wall begins to disappear, the idiozome completely disappears, but the chromatoid body can sometimes be seen clearly in the cytoplasm.

B. The growth period of the spermatocyte of the rabbit.

The resting stage:—The resting spermatocytes are found always in contact with spermatogonia arranged directly within the wall of the tubule. The nuclei usually contain, like those of the resting spermatogonial cells, many chromatin masses and several nucleoli (Fig. 146). Regarding the chromatin nucleolus, no phenomenon of dimorphism is to be observed in this stage.

The leptotene stage:—The chromatins soon condense into apparently continuous, slender filaments (Fig. 96). These immediately begin to converge to one pole of the nucleus where the idiozome is situated. During this stage the chromatin threads become arranged in a tangled mass, but no parallel arrangement can be seen (Fig. 96).

The synaptic stage:—Following upon the leptotene stage comes the synaptic stage. As in the horse the leptotene threads become aggregated at one pole of the nucleus where the idiozome is situated (Fig. 97). Finally the spiremes are gathered together and form a mass, but, by careful observation, their individuality can clearly be made out (Fig. 98). With the aggregation of the chromatin spiremes the nuclear wall expands rapidly, leaving a clear space on the other side of the nucleus (Fig. 97–99). At the end of this stage the parallel arrangement of the spiremes can very often be seen. The whole mass of the chromatin threads begins to move towards the center of the nucleus, the clear space thus gradually disappearing, while the nuclear wall becomes spherical (Figs. 99, 100).

As in the guinea-pig described by DUESBERG ('11) the mitochondrial

granules appear in small numbers which are usually gathered near the idio-
zome (Figs. 98, 99).

The pachytène stage:—The number of spiremes is considerably reduced,
appearing about half of the original number and fully twice as many as those
of the leptotène stage (Fig. 100). The movement of the chromatin spiremes
are carried out further until they spread throughout the nucleus, while the
cell gradually increases in size and the nuclear wall is more clearly defined
(Figs. 101, 148). In this stage two or more small spherical nucleoli appear,
which can clearly be seen in the section stained with AUERBACH's method
(Fig. 148).

The diplotène stage:—The cells rapidly grow in this stage, becoming
twice as large as in the leptotène stage, and the spiremes stain faintly with
iron-hæmatoxylin, and show a granular appearance (Fig. 101). Together
with the growth of the cell the spiremes become thicker, and in some
spiremes the longitudinal splitting appears distinctly in any preparation
(Figs. 102, 103). The spiremes shorten more and more until the various
bivalent chromosomes appear (Fig. 104).

As in the mouse in this stage the spiremes increase the affinity for acid
fuchsin, which proceeds parallel with the growth of cells, attaining its
maximum at the end of this stage (Fig. 150).

The nucleolus is conspicuous throughout this stage, and attains its greatest
size at the end of this stage (Figs. 149, 150). As in the mouse the chromatoid
body appears at the beginning of this stage, being stained like the nucleoli
(Fgis. 102, 105, 150).

During this stage the chromosome nucleolus which corresponds exactly
with that of the horse can be clearly seen (Figs. 101–103, 150).

The prophase:—Finally the spiremes become shortened in length and
form many variously curved chromosomes, but the forms of the bivalent
chromosomes are different from those of the mouse (Fig. 105). In some
chromosomes the longitudinal splittings are very conspicuous, and form large
slits in the chromosomes (Fig. 104). Thus the ring-shaped chromosomes
appear, while in most of the smaller chromosomes the longitudinal splitting
does not appear at all but the chromosomes appear as bivalent rods (Fig.
105).

Among the bivalent chromosomes a short, large chromosome appears which may be the accessory one (Figs. 105, 106). At the end of this stage this body can not be made out, as every chromosome now becomes shortened and the bivalent form almost disappears.

In this stage it is not difficult to distinguish each chromosome and so to count their number, as the chromosomes are distinctly separated (Figs. 104, 105). For counting the chromosomes, only those cells were selected in which the chromosomes are well separated. It was found that all such cells always contain twenty four chromosomes. Thus it is certain that the reduced number of chromosomes in the male germ cells is twenty four, accordingly the spermatogonial chromosomes are probably forty seven in number, consisting of forty six univalent chromosomes and an odd one.

The nucleolus usually disappears at the beginning of this stage, but sometimes it still remains till the end of this stage. In every stage it can clearly be discerned by its distinctive staining capacity with AUERBACH's method (Figs. 149, 150). The behavior of the mitochondrial granules and idiozome are entirely similar to that of the mouse.

III. The Reduction Division.

A. The reduction division in the mouse.

The first reduction division:—In the polar view of the equatorial plate of the metaphase the chromosomes are distinctly separated and so it is not difficult to make out every chromosome and to count them exactly (Figs. 37–41). In the early metaphase the characteristic form of the tetrad still appears, showing distinct and constant differences in size and form (Figs. 37, 38). In most of the metaphase the number of the chromosomes is always counted to be twenty which represents half the number of the chromosomes of the spermatogonia (Figs. 37, 41). When the chromosomes are compared according to their size it is found that, even though they form a series differing very gradually from the largest to the smallest, they can be classified in three groups; namely, three large sized, fifteen middle sized and two small sized ones (Figs. 38, 40, 41). If we compare the series of the spermatogonial chromosomes with that of the haploid ones, we can clearly recognize that the

bivalent chromosomes are formed by the conjugation of the homologous ones (Figs. 9–13).

The side view of the metaphase plate of the first division shows that twenty bivalent chromosomes are arranged in the equatorial plate with their short axis parallel to the latter (Figs. 43–45). Immediately they begin to divide at their ends where the spindle fibers attach (Figs. 46, 47). Whether this dividing line of the chromosome represents the conjugated plane of the univalent chromosomes or whether it is simply the longitudinal splitting which is comparable to that of the somatic chromosome, is difficult to determine positively. But judging from the method of synapsis and from the ring formation, this line of division seems to be equivalent to the conjugated plane of the univalent chromosomes. If it is so, then the division must be looked upon as a reducing one.

When every chromosome is simultaneously divided into two portions U-or V-shaped ones are not produced, but they simply assume the short rod-shape (Fig. 51). In well stained preparations previously treated with a modification of HANCE's method, two special chromosomes with different behavior can usually be seen at this period. These may be the sex-chromosomes and consist of a large X- and a small Y-chromosome. In the metaphase these XY-chromosomes are united to form a bivalent one, appearing as an ordinary bivalent chromosome. Together with the division of the ordinary chromosomes the bivalent sex-chromosome usually separates into its components, a large X and a small Y-chromosome, these are usually seen at the beginning of the anaphase, but they can often be seen at the late metaphase as well (Fig 46-51). In the metaphase these chromosomes are sometimes seen near the respective poles, while the ordinary ones still remain in the equatorial plate (Fig. 48). This shows that the division or the separation of the bivalent sex-chromosome precedes that of the ordinary ones and its components X and Y pass to the respective poles in advance of the latter.

When the chromosomes arrive at the respective poles they are usually separated and so it is not difficult to make out their individualities. In a good polar view of the anaphase we can distinguish two kinds of groups of chromosomes, the one containing the large X-chromosome and the other the small Y (Fig. 13). If we now pick out all the chromosomes and arrange

them carefully in accordance with their form and size, it will be plainly shown that they are represented by pairs, with the exception of the sex-chromosomes (Fig. 13). In the telophase all the chromosomes become so closely aggregated that their individual outlines are entirely lost to view.

The second reduction division:— In the second reduction division the chromosomes have a tendency to gather into a mass, which makes it difficult to count them with certainty. In fairly good stained preparations the number of chromosomes is estimated to be twenty, but the sex-chromosomes can not be clearly distinguished (Figs. 59–62).

As in the case of the horse and cattle the second pairing of the chromosomes reported by GUYER ('10), JORDAN ('12) and WODSEDALEK ('13, '14, '20) could not be seen. It has also been recently denied by HANCE ('17) in the pig and by ALLEN ('18) in the rat. It is very likely that such an apparent pairing of the chromosomes is produced as the result of a poor fixation of the material in which the chromosomes are massed together.

In the equator of this division all the chromosomes become so placed that the transverse constriction of each of them coincides with the equatorial plate, and it is along this plane that they are divided at the same time, no special chromosomes with different behavior being seen among them (Figs. 62–64). This constriction of the chromosome represents the longitudinal splitting which is comparable to that of the somatic chromosome. If it is so, it will be conjectured that the real character of the second division is simply an equation division, the sex-chromosomes being also divided into two by the longitudinal splitting like the ordinary ones. As in the first division, in the anaphase of this division the chromosomes are distinctly separated and for a short time maintain their individualities (Fig. 65). In the telophase the chromosomes also gather together so closely that their individualities become entirely lost to view (Fig. 66).

The mitochondria:—During the first reduction division the mitochondrial granules lie outside the spindle, being scattered throughout the cell body (Fig. 42). Sometimes linear arrangement of them is to be seen in this stage (Fig. 42). When the cells divide into two, they remain undivided and seem to be equally distributed in the cytoplasm of the daughter cells. In the first division most of the granules seem to attain their greatest size, but it is

difficult to determine this with any certainty since their size is too small to measure. In the second reduction division the mitochondria repeat the same behavior as in the first (Fig. 63).

The chromatoid body:—During the first division the chromatoid body usually lies near the pole of the spindle (Fig. 43). At the telophase it remains without division and enters into one of the daughter cells. Sometimes beside the chromatoid body a large round body appears which is stained deeply with acid-fuchsin like the chromatoid body (Fig. 45). In the succeeding stage this body can not be distinguished from the chromatoid body. Judging from the behavior and situation this body is probably the remnant of the nucleolus which appears in the early metaplase, but it is uncertain whether it remains till the transformation of the spermatid as the true chromatoid body, or disappears in the telophase of the first division. In the second spermatocyte the chromatoid body is very conspicuous and is probably the same as that seen in the telophase of the first division. In the second reduction division the chromatoid body repeats the same behavior as in the first, but in the telophase it lies near the cell plate (Figs. 62-64, 66, 141). When the cell is divided into two the chromatoid body enters into one of the daughter cells (Fig. 142). Sometimes some extra small bodies appear which are probably produced by division of the chromatoid body.

It is remarkable that in the second spermatocyte the chromatoid body becomes more conspicuous and is deeply stained with acid-fuchsin (Figs. 141, 142).

The resting stage of the secondary spermatocyte:—As in other mammals the resting stage of the secondary spermatocyte is found in the mouse. The nuclei of the resting secondary spermatocytes contain several chromatin masses and no special chromosome nucleoli can be found. The idiozome, the chromatoid body and the mitochondrial granules appear in this stage, the latter being scattered throughout the cytoplasm.

B. The reduction division in the rabbit.

The first reduction division:—In the metaplase of the first reduction division the chromosomes have a tendency to mass together so closely that it is difficult to make out their individualities distinctly (Fig. 108). That thsi

aggregation of the chromosomes in the first division is to be regarded as the natural state of the chromosomes at this stage and not due to the influence of the fixation may be concluded from the fact that the diploid chromosomes occuring in the same tubule are distinctly separated from each other. In a good polar view of the equatorial plate of the metaphase the number of the chromosomes is rather difficult to determine but may be counted as over twenty (Fig. 103).

In the equatorial plate of this division all the chromosomes, except the accessory one, become so placed that the constriction of every one of them coincides with the equatorial plate (Figs. 107, 108). The division begins to occur at this point of constriction where the spindle fiber attaches and soon the chromosomes become separated into their components (Fig. 109).

If this plane of division represents the line of the conjugation of two univalent chromosomes, then the conjugated univalent chromosomes must be separated and so the first division is the reducing division. When the chromosomes thus separated move towards the respective poles, U- or V-shaped ones can not be produced, they simply remain as short rod-shaped ones.

In the metaphase when the ordinary chromosomes begin to divide, the accessory passes undivided to one pole of the spindle in advance of the ordinary chromosomes and can easily be distinguished from the latter by its special form (Figs, 106, 107). Its behavior corresponds almost exactly with that of the other mammals. Even though we can not trace this chromosome as exactly as that in the horse and cattle, we need not hesitate to identify it with the same. When all the chromosomes arrive at the poles they are gathered so closely together that their individual outlines can not possibly be made out, the accessory at the same time disappearing from view (Fig. 110).

The second reduction division :—As in the first division, so in the second division the chromosomes have a tendency to gather into a mass so closely together that it is difficult to distinguish every chromosome and so to count them (Fig. 112). In this division all the chromosomes are so arranged that their transverse constrictions which probably represent the longitudinal splitting, coincide with the equatorial plate, and thus they begin to divide into two portions by the separation of the daughter chromosomes at the

constrictions, the accessory being divided into two at the same time (Figs. 111, 112). If this view be right, and we have reason to think it so, the second division is simply an ordinary mitosis.

At the anaphase when the chromosomes arrive at the poles they are as usual gathered together into a mass, and it is difficult to distinguish their individualities (Figs. 114, 115).

The mitochondria:—In the metaphase of the first reduction division the mitchondrial granules lie outside the spindle, being scattered all over the cell body. At the anaphase they remain undivided, but after the division the granules seem to be approximately equally distributed in the daughter cells. In the resting secondary spermatocyte they are also seen scattered all over the cell. In the second reduction division they repeat the same behavior as in the first division.

Even though the amount of the mitochondrial granules vary considerably according to the stage, it is clear that they are of very small number compared with those of the mouse. As in the mouse the size of the granules is variable, not only in the cells of different stages but also in those of the same stage.

The chromatoid body:—In the first reduction division the chromatoid body like that which we found in the mouse rarely appears (Fig. 110), this is also the case in the secondary spermatocyte (Fig. 111).

The resting stage of the secondary spermatocyte:—The nuclei of the resting secondary spermatocytes contain several chromatin masses; and no special chromatin nucleolus can be found among them.

IV. THE SPERMATIDS UP TO THE FORMATION OF THE SPERMATOZOA.

A. Spermatid in the mouse.

Immediately after the second division, the chromosomes begin to break up and the nucleus enters the resting stage (Fig. 143). The resting nucleus of the spermatid usually contains several chromatin masses and a few chromatin granules which are scattered along the linin threads (Fig. 143). The chromatins are gradually gathered together in the center of the nucleus where the nucleolus is situated (Figs. 67, 68, 144). The nucleolus can

clearly be seen with AUERBACH's method, while with iron-hæmatoxylin this appears as a chromatin nucleolus. Thus the dimorphism as regards to the existence of the chromatin nucleolus, can not be seen.

In the cytoplasm the chromatoid body or "chromatoider Nebenkörper" is always conspicuous, stained deeply with acid-fuchsin by AUERBACH's method, while with iron-hæmatoxylin it is difficult to find the distinction between this body and the chromatin mass (Figs. 67, 143).

The centrosome can clearly be seen in this stage, usually lying near the nuclear wall (Fig. 67). At the beginning of this stage the idiozome distinctly appears in close contact with nuclear wall, showing a sharp contour (Figs 68, 143). As has already been described by BENDA ('91) and by MEVES ('99) small granules can be seen within the idiozome (Fig. 67, 68). A small quantity of the mitochondrial granules appears in this stage, being distributed all over the cell body (Fig. 69).

B. The formation of the spermatozoa in the mouse.

PERIOD[1] I.

The nucleus :—The small spheric nucleus gradually enlarges and the chromatin granules begin to disappear, leaving a central mass of chromatin behind (Fig. 67–70). This enlargement of the nucleus is probably due to the fact that at this stage the spherical nucleus begins to flatten. Simultaneously with this the nucleus gradually moves towards one side of the cell which is destined to become the anterior end of the spermatozoön, while a large amount of the cytoplasm accumulates at the posterior part of the cell body (Figs. 70, 71).

The centrosome :—In this period two centrosomes become clearly visible ; these lie at first side by side, but soon move towards the nuclear wall (Figs. 69, 70). One of these centrosomes which is destined to become the anterior one, comes to be placed in contact with the nuclear wall, while the fine filament which later becomes the axial filament of the spermatozoön, begins

1. The four periods into which the formation of the spermatozoa is divided, is in accordance with the work of MEVES ('99), although it is not possible to draw any definite line of demarcation between the two successive periods.

to proceed from the posterior one backward towards the surface of the cell (Figs. 69-71).

The idiozome :—Later on the granules of the idiozome gradually grow and these collect together and form a large mass which usually lies close to the wall of the idiozome, being surrounded by a clear space (Figs. 67-69). When the two centrosomes appear this mass is found to lie in close contact to the anterior part of the nuclear wall where a slight depression appears, while the remnant of the idiozome in which vacuole can be seen, gradually diminishes in size, becoming more and more homogeneous (Figs. 69-81).

The mitochondria :—A small number of the mitochondrial granules still remains in the cell body, the main portion of them being gathered at the posterior part of it (Fig. 69).

The chromatoid body :—The chromatoid body remains without any change and usually lies near the centrosome, appearing as a spheric body (Fig. 70).

PERIOD II.

The nucleus :—At the beginning of this period the nucleus begins to elongate and finally assumes a pear-shape (Fig. 72). Some of the chromatin granules begin to collect on the inner surface of the nucleus, while several masses are left behind, and are so faintly stained with iron-hæmatoxylin, that the nucleus appears more or less homogeneous (Figs. 72-74).

The centrosome :—The anterior centrosome which is situated on the nuclear wall, gradually grows and flattens, while the axial filament elongates more and more until it proceeds backwards and projects out of the cell body (Figs. 72-74).

The acrosome :—The acrosome which is formed by the condensation of the granules of the idiozome now grows and flattens, to spread out finally on the anterior surface of the nuclear wall, while the remnant of the idiozome gradually diminishes in size (Figs. 72-74).

"Schwanzmanschette" :—At the end of this stage the "Schwanz-manschette" appears at the posterior part of the nuclear wall (Fig. 72). Its form is entirely similar to that of the guinea-pig, as described by MEVES ('99), but the filamentous structure as indicated by him can not be seen.

Within the "Schwanzmanschette" the centrosomes, the axial filament and the "chromatoider Nebenkkörper" are enclosed, the latter having attained the greatest size at the beginning af this stage (Figs. 72-74).

The mitochondrial granules:—The mitochondrial granules are scattered throughout the cell body and again increase in number (Figs. 72-74).

PERIOD III.

The nucleus:—The nucleus continues to elongate until its anterior part begins to bend towards one side which is destined to become a ventral part of the spermatozoa (Fig. 75). At this stage all the chromatin masses entirely disappear, and the nucleus thus becomes homogeneous, but takes a deep methyl-green stain with AUERBACH's method (Fig. 75) From this fact it seems more probable that the chromatin masses break into very small particles and are distributed throughout the nucleus, the main portion of these particles being condensed at the nuclear wall. At the post-ventral side of the nuclear wall a large depression appears where the centrosome is situated (Figs. 75-77).

The centrosomes:—The posterior centrosome begins to divide into two, while the anterior one comes to be placed in close contact to the nuclear wall (Figs. 75, 76). Of these two centrosomes thus formed by division of the posterior one, the smaller one is placed nearer the nucleus, while the other is placed outside it. The smaller one retains its spherical shape, and has the axial filament attached to it. The larger centrosome now assumes a ring shape and gradually increases in size, while the axial filament comes to pass through the ring (Fig. 75, 77). Soon after the ring-shaped centrosome begins to move backward along the axial filament (Fig. 78).

The mitochondrial granules:—The mitochondrial granules are now gathered into several groups within the elongated cell body, and these soon begin to arrange themselves around the axial filament (Figs. 77, 78). Besides the mitochondria other large granules can be seen, stained deeply with osmic acid (Fig. 83). These may be fat-granules which probably correspond to those of the rat, as described by DUESBERG ('08 b).

The acrosome:—The acrosome assumes a pear-shape and attaches at the apex of the head of the spermatozoa, while the rest of the idiozome completely disappears (Figs. 75-78).

' Schwanzmanschette" and "chromatoider Nebenkörper":—When the
ring-centrosome begins to move backward, the "Schwanzmanschette" gradually
disappears (Figs. 77, 78'. The fate of this membrane could not be determined,
but it seems probable that, as HERMANN ('98) long ago described, this membrane
is of use for the development of the middle piece of the spermatozon.

The "chromatoider Nebenkörper" is always placed within the "Schwanz-
manschette" during this period, diminishing gradually in size till it finally
disappears.

PERIOD IV.

The nucleus is somewhat elongated, becoming homogeneous in appearance
(Figs. 80, 81, 84). Together with this, the mitochondrial granules gradually
collect around the axial filament, and arrange themselves spirally around it,
the extreme end of the granules being marked by the presence of the ring-
shaped centrosome situated on the posterior end of the cell (Figs. 80, 81, 84).
At the beginning of this period the anterior centrosome becomes divided into
two in the direction along the surface of the nuclear wall, but still connected
with each other by a fine intervening fibre, and thus forming an elongated
dumbbell-shaped body lying close on the wall of the nucleus. Each of the
two ends of this body is now seen to be connected with the posterior
centrosome by a fine fibre (Figs. 80, 84). During these changes the cell body
becomes considerably elongated while its contents, including all the fat-granules,
is cast off as a cytoplasmic ball out of the spermatozoön, leaving only the axial
filament and the mitochondrial granules which now assume a beautiful spiral
shape (Fig. 84).

C. The spermatid of the rabbit.

As in the mouse the resting nuclei of the spermatids usually contain
many chromatin granules and a large irregular chromatin mass which lies
usually at the center of the nucleus (Figs. 116, 150). Besides the latter a
nucleolus can be seen in the preparation stained with AUERBACH's method
(Fig. 150).

In the cytoplasm the idiozome is conspicuous, while the chromatoid body
can not be found in most of the cells. But a very small body which

probably a portion of the chromatoid body sometimes appears (Figs. 116, 119). A few mitochondrial granules appear, most of them lying near the cell wall (Fig. 116).

D.   The formation of the spermatozoa in the rabbit.

As the transformation of the spermatid in the rabbit, with the exception of the centrosome and of the mitochondria, is almost similar to that of the mouse, we will chiefly consider the changes of the centrosome and the development of the middle piece of the spermatozoa.

When the granules of the idiozome collect into a large single mass and become attached to the anterior part of the nuclear wall, two centrosomes become clearly visible (Fig. 118). Of these the one which is destined to become the anterior centrosome, comes to lie close to the nuclear wall and grows rapidly, while the other assumes for a while its original position (Fig. 119). This latter now begins to send out a fine filament which recedes backwards toward the surface of the cell (Fig. 119).

This period thus corresponds exactly to the period I in the mouse. The anterior centrosome gradually grows larger and divides into two, lying side by side close to the posterior wall of the nucleus (Figs. 120, 121). Soon after the posterior one also divides into two, and the four centrosomes thus formed are connected with each other by fine filaments (Fig. 121). Together with these changes of the centrosomes the axial filament elongates more and more until it proceeds backwards and comes to project outside of the cell body.

The chromatoid body which was rarely found at the cell wall in the previous stage, entirely disappears in this stage.

The "Schwanzmanschette" which, as in the mouse, begins to appear with the elongation of the nucleus, becomes gradually smaller, when the four centrosomes are formed, till it finally disappears (Figs. 121–123).

Now the posterior two centrosomes gradually increase in size, becoming more conspicuous in the final development of the spermatozoa (Figs. 124, 125). The ring shaped centrosome found in the mouse and the other mammals could not be seen at all.

At the time when the two primary centrosomes become distinctly visible, a small number of the mitochondrial granules still remains near the cell wall,

which in a later stage seem to increase (Figs. 119, 120). The augmentation of them in this period was reported by DUESBERG ('08 b) in the rat and by JORDAN ('12) in opossum.

Later on the main portion of the cytoplasm moves backwards, assuming a rounded body, and comes to be placed entirely in front of the nucleus which now becomes more and more elongated, till it finally assumes its position as the head of ripe spermatozoön (Figs. 121, 123). During these changes the mitochondrial granules gradually collect in several groups and finally become arranged around the axial filament, while the "Schwanzmanschette" entirely disappears (Figs. 122-123).

In the middle piece of the ripe spermatozoa found in the tubule, about twenty four large granules can be counted arranged in two rows along the side of the axial filament (Figs. 124-125). From what is stated above it is clear that these granules are formed by the aggregation of the small mitochondrial granules.

General Considerations.

I.   THE CHROMOSOMES OF THE SPERMATOGONIA.

Number of chromosomes in rodents:—As to the number of chromosomes in the rodents there is a wide difference in opinion among the investigators.

In the maturation of the egg of the mouse, SOBOTTA ('95) and KIRKHAM ('07) reported twelve chromosomes, while LONG and MARK ('11) counted twenty chromosomes, in both the maturation divisions. YOCUM ('17) reported twenty chromosomes as the reduced number in the male germ cells of the mouse.

But, as far as I am aware, none of the investigators gave the positive diploid number of chromosomes in the mouse. In the rat DUESBERG ('08 a) reported twelve chromosomes as the reduced number. Recently ALLEN ('18) has counted thirty seven chromosomes in the spermatogonia of the rat, nineteen in the first reduction division.

In the rabbit WINIWARTER ('00) found that the somatic chromosomes vary from thirty six to eighty. BACHHUBER ('16) reported twenty two chromosomes as the diploid number and twelve as the reduced number in the male germ cells of the rabbit. STEVENS ('11) counted fifty six chromosomes in the

spermatogonia of the guinea-pig and he concluded that this number is probably correct.

The existence of pairs of chromosomes :—Since the chromosomes of the mouse are of large number and vary so gradually in size, that it is difficult to determine them accurately by only cursory observations, especially the existence of the pairs among the chromosomes and the constant relation with regard to their size and form are the points which require a thorough and careful study.

For the determination of the existence of the pairs among somatic chromosomes, measurements have been made by some investigators. MEVES ('11) in salamander, HANCE (,17) in the pig and Parmenter ('19) in some Amphibia (Amblystoma) measured the length of the chromosomes, while KATSUKI ('19) in silkworm measured the diameter and calculated the volume.

In the mouse it is difficult to determine the existence of the pairs of chromosomes by the comparison of their length only, as they are not straight but of various shapes. Nevertheless, if the size of every chromosome is constant in any definite period of the mitosis, and if it is possible to determine the true size of the chromosomes, it would be a very good method for the determination of the presence of the pairs, but it is very difficult to determine since the shapes of the chromosomes vary so very much.

As before stated, the writer therefore, tried to find out the paired chromosomes, basing the determination on their shape and size, as he thought that this would give more trustworthy results than either by calculating the length or the breadth only (pp. 211). Three things must, however, be considered in this method: these are, 1. The difference in the degree of the condensation of the particles composing the chromosomes, which may cause slight differences in the relative size and form. 2. The small difference in size between neighbouring chromosomes in the series of the chromosomes arranged according to the size makes it sometimes impossible to demonstrate beyond all doubt the presence of pairs among them. 3. It is possible that an error may occur when the chromosomes are drawn with the aid of a camera-lucida.

In spite of these considerations, it will be seen from Table II where the chromosomes are arranged according to their area, that the present method is a most reliable one, as it affords on the whole undeniable evidence that the chromo-

somes form a duplex series, even though from the above reason it can not be expected, that the homologous chromosomes will always be of the same size.

The relation between size of cells and that of chromosomes:—Moreover in Figs. 9–12 where the chromosomes are arranged in accordance to our present method, each of the homologous pairs is found to be almost similar in shape, so that we can fairly reach the conclusion that there exists a constant relation between their size and their form.

It has already been stated above that the size of the chromosomes seems to vary in accordance with those of the nuclei. This relation will be more readily understood from Text-fig. 1, where curve I indicates the relation of the size of chromosomes which are contained in the large cell, while curve II indicates that of the small ones. It is found that these two curves are almost parallel with one another. Judging from this fact it is evident that the size of cells as well as that of the chromosomes vary considerably according to the generation of the spermatogonia, the chromosomes in early generations being probably larger than those in the final generation.

The sex chromosomes:—It is remarkable that there are two different chromosomes which have no mate. One of them is larger than the other, and differs considerably in form from the neighbouring chromosomes of the series, while the other is the smallest one of the entire series.

The difference in size between this smallest chromosome and the neighbouring one is considerably larger in comparison with that occurring between our other pairs. The above data shows conclusively that these special chromosomes are XY-chromosomes.

The fragmentation of the chromosomes in rabbit:—As stated above the number of chromosomes in the germ cell of the rabbit is not constant but varies considerably. Vom RATH ('94) long ago found that the somatic chromosomes in the dog vary considerably. The same phenomenon was reported by WINIWARTER ('00) in the somatic cells of the rabbit. HANCE ('17 b) found that the number of chromosomes of the somatic cells in the pig is not constant but varies from forty to forty seven. He attributed cause of this variation in number to the fragmentation of certain chromosomes, and says: "Since the fragments are fairly uniform in length, the chromosomes must be educed by more or less equivalent amounts, and consequently we should not

expect to find the percentage relation between the pairs showing any marked variation from that found between the spermatogonial pairs."

But as stated above the observation of the chromosomes of the spermatogonia in the rabbit compelled us to recognize the following facts : 1. Certain chromosomes are considerably long and variously curved, and sometimes show constrictions. 2. In those cells in which a large number of chromosomes are found, the smaller ones are very numerous.

From these facts it is conceivable that as HANCE ('17 b) has stated of the somatic cells of the pig, the cause of their variation is probably due to the fragmentation of certain chromosomes. But it is very probable that this fragmentation is not to be looked upon as a normal process occurring in the spermatogonia but is due to the influence of fixation. A striking evidence in support of this view is that, in materials which were poorly fixed, the variation in number of chromosomes was especially more numerous than in those which were better fixed.

II. The Synizesis and the Synapsis.

The synizesis :— As mentioned above the slight polar aggregation of the chromatin threads can always be seen in the early stage of the spermatocyte in the mouse, while in the rabbit this aggregation is very conspicuous.

It is, however, difficult to determine whether this aggregation of the chromatin threads represents the normal state which occurs in the cycle of the spermatogenesis and is comparable to that of the horse and of cattle where the conjugation of the chromosomes may occur, or whether this is regarded as an artifact, being probably the result of the fixation. DUESBERG ('08 a) holds the latter view, where he says : " On peut aller plus loin et faire remarquer que, si dans un matériel bien fixé on n'observe pas de retractione de la chromatine, cet argument negatif a une beaucoup grande valeur que l'argument positif contraire ; car, s'il est impossible de mettre sur le compte des reactifs l'absence de synapsis, nous savons au contraire que les fixateurs, même les meilleurs, peuvent dans de mauvaises conditions, produire le synapsis."

1. In insects (Hemiptera), WILSON ('12) has stated that the contraction figure can not be regarded as an artifact. He proved that in some hemiptera this phenomenon is seen in the living cell.

HANCE ('17 a) also made a similar observation in the mammalian tissues,
He says: "Synizesis was not seen in this material except in the center of a
piece of tissue which was rather larger and where the fixative had not
penetrated." Thus he attributes the cause of the polarization of the spiremes
to the result of imperfect fixation of tissues. Again he says: "Even here it
is not the tight ball of threads figured so many but gives every evidence
that it is the result of the extraction of the fluid. In many preparations
where any evidence of the synizesis of thin chromatin threads occurs, there is
only a slight contraction if the threads away from the nuclear wall appearing
as though the fluid which had supported these threads had been removed.
The shrinkage appears to be equal from all sides, although occasionally a
cell is found with the chromatin threads massed at one side. In well teased
or small piece of tissue these same stages appear with the threads well
separated and there is no shrinkage away from the nuclear wall."

But in my materials the observation of the preparations compelled us to
admit the following facts: 1. Whatever fixations may be used, the synizesis
(contraction figure) can be seen in every part of the sections, though it is very
slight in the mouse. 2. This phenomenon occurs in the definite period of
the growth stage of the spermatocyte, and in very young stage, but never
in other stages. 3. At the end of this stage, the chromatin spiremes appear
in about half the original number and twice as thick as the leptotène stage.

Judging from these facts it seems most probable that the polar aggrega-
tion of the chromatin threads in the rabbit and in the mouse represents the
normal state which occurs in the definite period of the spermatocyte and
corresponds to that of the other mammals. Moreover it is a striking evidence
in support of this view, that in the rabbit, throughout the wall of the tubule
in which the cells are presenting the synapsis, the parallel arrangements of
the chromatin threads, without exception, show a decided contraction of the
threads.

As I have stated of the horse in the previous paper ('19), the leptotène
threads in the rabbit are aggregated to one pole of the nucleus where the
idiozome is situated. The same phenomenon was described by WODSEDALEK
('13) in the pig and JORDAN ('12) in opossum. MORSE ('09) found a similar
condition of the condensation of the chromatin threads in the spermatocyte

of certain cockroaches and came to the conclusion that it is due to some interaction between the chromatin spiremes and the centrosomes which gives rise to this phenomenon. BUCHNER ('10) more fully demonstrated the relation of the centrosome and other substances of the cell (nuclear as well as cyto-plasmic substance), where he says; "Das Centriol vermag Körper in Kern und im Plasma anzuziehen und vermag ferner die Kernmembran in seiner Nachbarschaft aufzulösen."

The synapsis:—As already described, in the mouse there is no indication of parasynapsis in this stage, while in the rabbit parallel arrangement of two univalent spiremes is seen to occur, which exactly corresponds with that of the horse,

In the rat ALLEN ('18) has shown the parasynapsis, but he did not indicate the parallel arrangement of the spiremes in this stage.

Only from observation of the spiremes in this stage have we reached the view that the method of synapsis in the mouse is different from that in the former the conjugation probably taking place by telosynapsis but in the latter by parasynapsis.

Nevertheless, in order to completely consider the question of the synapsis there are two significant facts which demand careful observation. The one is the transformation of chromatin spiremes in the post-synaptic stage and the other is the construction of chromosomes in the late prophase. In the post-synaptic stage the longitudinal splitting of the chromatin spiremes can usually be seen in the rabbit and also in the mouse. Whether the longitudinal splitting of the chromatin spireme is entirely the same as that of the somatic chromosomes, or whether this splitting is the result of the conjugation of the univalent chromosomes, is the most significant point in the determination of the method of the synapsis. The former view was maintained by GOLDSCHMIDT ('08), by FICK ('08), DUESBERG ('08 a), BUCHNER ('09) and by JORDAN ('12), whereas WILSON ('12) holds the latter view. By careful observations in the mouse, as already described, it is found that the ring-shaped chromosomes are formed by the union of the two ends of the conjugated univalent spiremes. Soon after the rings are closed up and the metaphase chromosomes appear. The longitudinal cleft of the chromosome which appear in the early metaphase (Fig. 36) must therefore be looked upon as a conjugated plane of the two univalent chromosomes.

These facts lead us to the conclusion that in the mouse the conjugation of chromosomes may occur by telosynapsis.

In the rabbit the ring shaped chromosomes appear to be formed by the separation of the univalent chromosomes along the plane of a longitudinal splitting. It has, however, been found that this, in fact, is not the case, the splitting seen in the chromosomes probably represents the line of conjugation of the univalent chromosomes, since the splitting appears only in the special chromosomes. From these facts it is more probable that the conjugation of the chromosomes in the rabbit takes place by parasynapsis.

Although the method of synapsis in the mouse is different from that in the rabbit, in both these animals, the conjugated chromosomes become disjointed. Thus by whatever method of the synapsis the conjugation of chromosomes may occur, it will come to the same result as regards the reduction of the chromosomes.

III.   The Sex-Chromosomes and the Nucleolus.

The sex-chromosomes:—As far as I am aware, sex-chromosomes in the rodents were first recorded by STEVENS ('12) in the guinea-pig. This was followed by JORDAN ('14) in the mouse, by BACHHUBER ('16) in the rabbit and by ALLEN ('18) in the rat.

JORDAN ('14) in the white mouse found the double nature of the hetero-chromosome which suggests a pair of idiochromosomes, but he believed this to be a double accessory chromosome or Wilson's X-chromosome. In the rabbit he found that heterochromosomes are wanting in the spermatocyte of the growth stage. In the male germ cell of the mouse YOCUM ('17) found the accessory chromosome which does not divide in the primary division, but does so in the secondary. As stated above in almost every stage of the spermatogenesis in the mouse XY- or idiochromosomes usually appear which correspond almost exactly with those of the insects (Wilson) and the guinea-pig (Stevens).

In the rabbit the accessory or the X-chromosome can be seen in the growth period of the spermatocyte and in the reduction division, but the occurrence of the dimorphism of the spermatozoa as regards to the existence of this chromosome can not practically be determined.

From the observation of the spermatogonial chromosomes as well as those of the first reduction in the mouse, it is conceivable that with regards to the sex chromosomes dimorphism must exist among the spermatozoa and so a difference may exist between the chromosomes of male germ cells and of the female.

The nucleolus:—In the spermatocyte of the mouse a single large nucleolus appears while in the rabbit two or more can be seen. These can not be distinguished from the chromosomes in the preparation stained with iron-haematoxylin, while with AUERBACH's method these can clearly be made out.

The existence of the nucleolus in the spermatocyte has been reported by many investigators in several kinds of animals. In mammals it is described by STEVENS ('11), DUESBERG ('08 a), JORDAN ('14) and ALLEN ('18). All these investigators, with exception of JORDAN ('14), agree that the nucleolus appears at the post-synaptic stage and disappears in the prophase of the first maturation division.

JORDAN ('14) believed that in mammals the nucleoli almost invariably disappear before the synapsis and can thus produce no confusion with the heterochromosomes in those stages where the latter are most conspicuous.

As to the physiological meaning of the nucleoli of the germ cells, WILSON ('19) in accordance with HACKER's ('99) interpretation stated that, "the nucleoli of the germ cells are, in some cases at least, accumulation of by-products of the nuclear action, derived from the chromatin either by direct transformation of its substance, or as chemical cleavage-product or secretions."

As stated above in the mouse and also in the rabbit the nucleoli appear at the post-synaptic stage and grow gradually, attaining its greatest size in the prophase. When the chromosomes become stained with methyl-green with AUERBACH's method, this body begins to diminish in size and finally disappears from view in the late prophase. Moreover it is a remarkable fact that when the growth of the cells attains to the maximum, the chromosomes and the nucleoli stain similarly with AUERBACH's method.

These facts force us to the conclusion that the nucleolus does not represent an accumulation of the by-products of the nuclear actions but consists of ground substance (plastin?) and nutritive substance? which is taken up by the nucleus from the cytoplasm; the latter probably used for the growth of the nucleus.

A similar view was propounded by MONTOGOMERY ('12) in his study on

Euschistus. He says: " In the spermatocyte they (plasmosomes) arise in close
contact with the nuclear membrane, and at the same time in connection with
the end of the autosome, which would suggest that the plasmosome is either
the joint product of chromatin and cytoplasm, or else represents substance
taken up by the nucleus from the cytoplasm."

IV.   The Growth of the Chromatin Spireme.

In the prophase of the primary spermatocyte, together with the growth of
the cell the chromatin spiremes grow considerably. At this stage they are
stained faintly with iron-hæmatoxylin, while their affinity for acid-fuchsin
gradually increases. A careful observation shows that this change of the stain-
ing capacity is due to the accumulation of the achromatic substance within
the chromatin spiremes.

This change of the staining capacity proceeds with the growth of
the cell body as well as that of the nucleus, until the bulk of the cell
attains its greatest size. In the metaphase of the first reduction division
the achromatic substance of the chromosome entirely disappears, and the
chromosomes are stained deeply with methyl-green with AUERBACH's method.
From these facts it is most probable that the achromatic substance of the
chromosome is used up for the chromatins in the prophase. A similar pheno-
menon has already been described by BONNEVIE ('08). He says: " Während
nach dem obigen das Wachstum der Chromosomen in einer Zunahme ihrer
Chromatinsubstanz besteht, scheint die während der Prophase erfolgende
Volumzunahme in einer durch Flüssigkeitanfnahme eingeleiteten Neubildung
achromatischer Substanz zu bestehen, und zwar so, dass ihre Menge von der
Grösse jedes Chromatinfadens bestimmt wird."

Moreover as to the structure of the chromosome his interpretation is as
follows: " Die neu gebildete achromatische Substanz scheint durch eine innere
Differenzierung der Chromosomen in ihrer Mitte angesammelt und von einer
oberflächlich gelegenen Schicht chromatischer Substanz umgeben zu werden."

V.   The Mitochondria.

The behavior of the mitochondrial granules in the mouse and the rabbit
is, except in some points, entirely similar to that described by DUESBERG ('11)

in the guinea-pig. He states: " Les observations, encore rares d'ailleurs, sur les chondriosomes des cellules séminales des Vertébrés, montrent que, si dans les classes inférieures (Amphibiens) il existe des chondriosomes de forme filamenteuse, la forme granuleuse paraît être la règle chez les Mammifères. Cette forme se maintient pendant les divisions de maturation : on observe bien, pendant la seconde division de cobaye, quelques chondriomites, mais la formation de chondriocontes reguliers, comme chez les Insectes, n'a pas encore été signalée jusqu'ici. Dans la spermatide des Mammifères, les mitochondries ne se condensent pas en corps homogène, comparable au Nebenkern, mais restent individualisées. Tous les observateurs sont d'accord sur leur sort final : elles forment une gaine, de structure variable, au filament axile du spermatozoïde." As to the process of the arrangement of the mitochondrial granules around the axial filament of the spermatozoa, contrary to my observation, he states that " le processus de la formation de la gaine mitochondriale débute par conséquent, chez le cobaye comme chez le rat, au voisinage de la tête." In my materials, on the other hand, the mitochondrial granules begin to arrange around the axial filament near the posterior cell wall.

With regard to the origin of the mitochondrial granules the opinions of the investigators do not agree, some (Goldschmidt, Buchner, Jordan) taking the view that these granules are formed by extrusion from the nucleus, while others (Meves, Duesberg) hold for the cytoplasmic origin. JORDAN ('12) in opossum, though could not directly observe the extrusion of the granules through the nuclear membrane, concluded that the mitochondrial granules originate from the nucleus. This is based upon the following facts : 1. Within and without the nucleus many granules appear which have a similar form and staining capacity to those of the mitochondrial granules. 2. In these cells one half of the periphery of the nucleus becomes surrounded by a compact mass of spherical or bivalent chromidia closely adhering to the nuclear wall. 3. The cell in this condition is characterised by the absence of chromatin particles within the nucleus. 4. The appearance of the chondriosomes in the cytoplasm is coincident with the disappearance of the chromidia on the nuclear membrane.

In my materials it is hard to make sure whether the mitochondrial granules arise from the cytoplasm or from the nucleus. Such granules as

those of the opossum can not be seen within or without the nucleus, but
in the leptotene as well as the synaptic stages a small number of the
mitochondrial granules usually appear in the cytoplasm. As DUESBERG ('11)
stated it is true that in the synaptic stage most of the granules always
appear near the pole of the nucleus where the chromatin spiremes converge,
and that they slightly increase in number. But it can not be admitted that
this increase in number of the granules is due to the extrusion of chromidial
particles from the nucleus, for the nuclear wall appears distinctly, and neither
the granules nor the particles can be found within or without the nucleus at
the converging point of the chromatin threads. But from actual observation it
is more probable that the mitochondrial granules do not originate from the
nucleus in the synaptic stage, they usually exist in the cytoplasm throughout
every stage and increase by division of the original ones. A number of facts
favourable for this view are to be seen in my materials, of which the following
can be cited: 1. The mitochondrial granules are usually found in the sperma-
togonial cells. The same facts have been reported by DUESBERG ('11) in the
guinea-pig and JORDAN ('12) in opossum. 2. The growth of every granule can
clearly be seen in the prophase of the first division. 3. In th same cell the
size of the granules varies considerably. 4. Lineal arrangement of the granules
can sometimes be seen. 5. The number of the granules differs considerably
in different stages of the cells.

The only difficulty which confronts us in the assumption of the cytoplasmic
origin of the mitochondrial granules, is perhaps the fact that in the synaptic
stage they are always gathered near the pole where the idiosome situated. But
this difficulty may be interpreted as follows: By the enormous expansion of
the nuclear wall at this stage, the cytoplasm becomes pushed towards the pole
where the idiozome is situated, and with this the mitochondrial granules also
move toward the same pole. This change of the position of the granules can,
however, be ascribed to the attraction of the centrosomes as BUCHNER ('10)
indicates.

VI. THE CHROMATOID BODY.

The chromatoid body was long ago described in mammals by many
investigators (Meves, Hermann, Lenhossék, Niessig and Duesberg). Recently

it has been described by WOODSDALEK ('14) in the horse, BACHHUBER ('16) in the rabbit and ALLEN ('18) in the rat. In insects this body was accurately described by MONTGOMERY ('11) and WILSON ('13).

But its origin and function are still a question. It is already known that in the spermatid of the mouse (C. Niessig) and of the rat (Meves) this body is very conspicuous, while in the guinea-pig (Meves) it disappears at the beginning of the development of the spermatozoa. MEVES ('99) in the guinea-pig showed that the chromatoid body is stained as the nucleoli. He says: " Ich selbst habe von Färbungen, welche geeignet sind, über die Natur des chromatoiden Nebenkörpers Aufschluss zu geben, nur (nach Sublimatfixirung) die Ehrlich-Biondische Dreifachfärbung angewandt, bei der er sich ebenso wie die Nukleolen intensiv rot färbt; ich kann also jedenfalls Moore nicht beistimmen, dass es sich um eliminiertes Chromatin handelt." DUESBERG ('11) also in the guinea-pig found the same phenomenon by using BENDA's method. ALLEN's ('18) observation in the rat is different from that of many other investigators as well as from mine. His description on its behavior and on its fate is as follows :" Its first positive appearance is in the late prophase stage of the first spermatocytes after the disappearance of the nuclear membrane. At first it appears to be near the chromosomes, but at a later stage it is always found well out in the cytoplasm. In some metaphase cells it is doubled. It is lost during the anaphase of the first spermatocytes and during the interkinasis stage, but reappears in the second spermatocytes. Nothing of equivalent form is found in the spermatids. In these cells, however, there is a mass lying near the nucleolus which stains like chromatin. It develops intensity of staining reactions as the spermatids advance in differentiation. In its fuller development it is as in figure 1, spermatid 3, where it appears as a globular body, but much larger and staining more deeply than the chromatoid body."

In my materials, as stated above, the chromatoid body is conspicuous from the prophase of the first division up to the transformation of the spermatids, and as MEVES ('99) and DUESBERG ('11) indicated, it stains deeply with acidfuchsin with AUERBACH's method. As to the fate of this body there is a difference between the mouse and the rabbit.

In the mouse it remains near the centrosomes within the "Schwanz-manschette" during the development of the spermatozoa, while in the latter it

usually disappears during the second division. Moreover, it is obvious that when the cell is divided into two it enters into one of the daughter cells without division, which produces two kinds of the spermatids in the mouse, the one with and the other without the chromatoid body.

From these it seems more probable that the chromatoid body is not an essential organ for the development of spermatozoa. Although its origin can not be determined with any certainty, from the period of its appearance and its staining reaction it seems more probable that the chromatoid body is not a proper cytoplasmic structure but originates from the nucleus. Its chemical nature seems to be different from that of the chromatin granules but is similar to that of the nucleoli which appear at the growth period of the spermatocyte.

Summary.

I.   Observation in the Mouse.

1.   The resting nuclei of the spermatogonial cells usually contain one large nucleolus and several chromatin masses.

2.   The number of spermatogonial chromosomes may be counted as forty. According to size and form, these are found to be in pairs. Every chromosome simultaneously begins to divide at one end where the spindle fiber attaches; no special chromosomes with different behavior are to be seen among them.

3.   In the young spermatocyte a slight polar aggregation of the chromatin threads usually appears, which corresponds to the synizesis of other animals.

4.   In the post-synaptic stage when the nucleolus appears the chromatin spiremes are stained with both methyl-green and acid-fuchsin at the same time with Auerbach's method. Together with the growth of the cells and of the nucleoli, this change of staining capacity increases, attaining the maximum in the prophase stage in which the ring shaped chromosomes begin to appear. At the late prophase the chromosomes are again stained with methyl-green only. In this stage the nucleolus, except in some few cases, entirely disappears.

5.   In the prophase several kinds of the ring shaped chromosomes appear which are condensed to the bivalent chromosomes in the metaphase of the first division. The number of the bivalent chromosomes may be counted as twenty.

6.   In the first division the chromosomes are divided along the conjugated planes; thus the first division is a reducing one.   In the second all the chromosomes become so placed that their longitudinal splittings coincide with the equatorial plane, and along this line all the chromosomes as well as the XY are divided at the same time; thus the second division is an equation division.

7.   The XY-chromosomes exist and can be traced with certainty up to the primary spermatocyte.

8.   The chromatoid body first appears at the early prophase.   In the reduction division this body enters undivided into one of the daughter cells and disappears in the "Schwanzmanschette" at the formation of the spermatozoa.

9.   The mitochondrial granules appear in the spermatocyte as well as in the spermatogonia, but they increase in number during the growth stage.   In the spermatid they become arranged spirally around the axial filament.

10.   In the spermatogonia and the spermatocyte the centrosomes could not be seen.   Its behavior in the development of the spermatozoa is almost similar to the condition found by DUESBERG ('08) in the rat.

II.   OBSERVATION IN THE RABBIT.

1.   The resting nuclei of the spermatogonial cells usually contain many chromatin masses and several nucleoli.

2.   The number of spermatogonial chromosomes is considerably varied.

3.   The resting primary spermatocytes usually appear.

4.   In the synaptic stage the chromatin spiremes aggregated at one nuclear pole where the idiozome is situated.   In this stage the parallel arrangement of the chromatin spiremes is clearly to be seen.

5.   In the prophase several ring-shaped chromosomes appear which are different in appearance from those of the mouse.   In this stage the number of chromosomes may be counted as twenty four.

6.   In the growth period two or more nucleoli can usually be seen, similar to those of the mouse in their behavior.

7.   The first division is a reducing one and the second an equation.

8.   The chromosome nucleolus or the accessory chromosome can be traced

throughout the growth stage and the reduction division. The behavior of this chromosome is entirely similar to that of the horse.

9. The behavior and form of the mitochondria are entirely similar to those of the mouse.

10. The chromatoid body appears in the early prophase. This body can be seen in the reduction division, but usually disappears in the secondary spermatocyte.

11. The behavior of the centrosome and of the idiozome in the formation of the spermatozoa, except in some points, is entirely similar to that of the guinea-pig, reported by MEVES ('99)

III. CONCLUSION.

1. From the results obtained by the measurement of the size of the spermatogonial chromosomes, it is found that pairs of chromosomes exist and that there is a constant relation between their size and their form. In the series of chromosomes arranged according to the size and form, two special chromosomes can be seen which are probably the sex-chromosomes.

2. The variation in the number of chromosomes in the rabbit is probably due to the fragmentation of certain chromosomes caused by the fixation of the materials.

3. The synisesis is the normal process which occurs in the definite period of the spermatocyte.

4. The conjugation of the chromosomes probably takes place by te'osynapsis in the mouse and parasynapsis in the rabbit.

5. From the behavior of the sex-chromosomes it is conceivable that with regards to the existence of the sex-chromosomes, dimorphism must exist among the spermatozoa.

6. The nucleolus of the spermatocyte does not represent accumulations of by-products of the nuclear actions but consists of the ground substance (plastin?) and the other achromatic substance which is probably to be used in the growth of the chromatin spiremes.

7. The change of staining capacity of the chromatin spiremes in the growth period is due to the accumulation of the achromatic substance in the chromatin epiremes.

8. The mitochondrial granules do not originate from the nucleus in the early stage of the spermatocyte, but exist in the cytoplasm from the beginning.

9. The chromatoid body is not an essential organ for the development of the spermatozoa and probably originates from the nucleus during the growth period of the spermatocyte.

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EXPLANATION OF PLATES.

All figures were drawn with aid of a camera-lucida, using a Zeiss 1.5 mm. apochromatic objective and compensating ocular no. 12, except figs. 130, 133 which were drawn with Zeiss 3 mm. apochromatic objective and compensating ocular no. 6. All the figures on Pl. IV, V, VI, VII, figures 82–84 on Pl. VIII, and figures 126–144 on Pl. X are from mouse. Those in Pl. IX, figures 85–102 on Pl. VIII and figs. 145–151 are from rabbit.

PLATE IV.

All the figures drawn from mouse.

Fig. 1.　Spermatogonium in resting stage, showing chromatin masses and nucleolus.

Fig. 2.　Spermatogonium in early prophase, showing many chromatin rods.

Fig. 3.　Spermatogonium in late prophase.

Figs. 4, 5.　Polar views of metaphase plates of spermatogonia, showing forty chromosomes.

Fig. 6.　Polar views of metaphase of spermatogonium, showing mitochondrial granules.

Fig. 7.　Side view of metaphase of spermatogonium.

Fig. 8.　Side view of anaphase of spermatogonium.

Figs. 9–10.　Chromosomes of spermatogonia arranged according to their area, showing pairs of chromosomes and two special chromosomes.

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Fig. 13.　Chromosomes of anaphase of first reduction division, showing pairs of chromosomes and two special chromosomes.

Fig. 14.　Side view of late anaphase of spermatogonium.

Fig. 15.　Leptotène stage of spermatocyte.

Figs. 16, 17.　Spermatocytes in synaptic stage, showing mitochondrial granules.

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PLATE V.

All figures are from mouse.

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Fig. 26.　Spermatocyte in late post-synaptic stage, showing mitochondrial granules.

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Figs. 28–33.　Spermatocytes in prophase of first division, showing various ring-shaped chromosomes.

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All figures are from mouse.

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All figures are from mouse.

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Fig. 62. Side view of metaphase of second reduction division.

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Figs. 67, 68. Spermatids, showing idiozome, chromatoid body and centrosome.

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PLATE VIII.

Figs. 82-84 are from mouse, Figs. 85-102, from rabbit.

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Fig 93. Side view of metaphase of spermatogonial division, showing mitochondrial granules

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Figures 126–144 are from mouse; Figs. 145–151, from rabbit.

All figures were drawn from preparations stained with AUERBACH's method.

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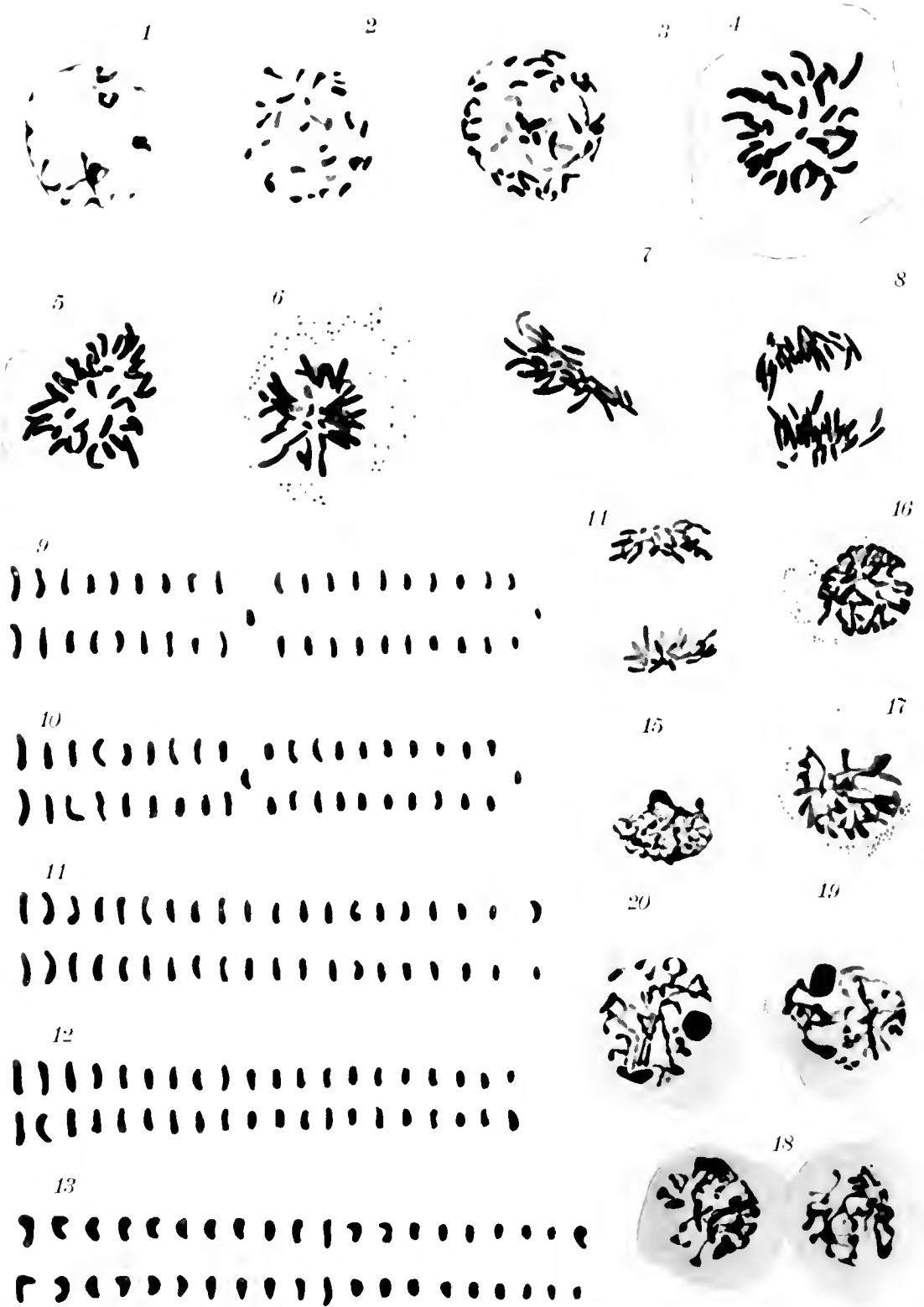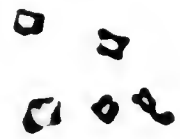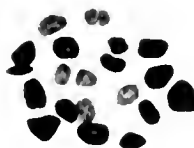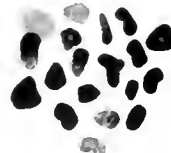
Plate IV.

Plate VI.

Plate VII.

Plate VIII.

Plate IX

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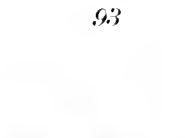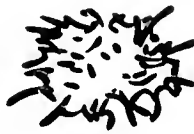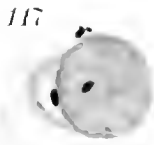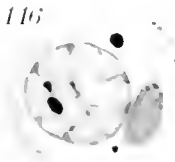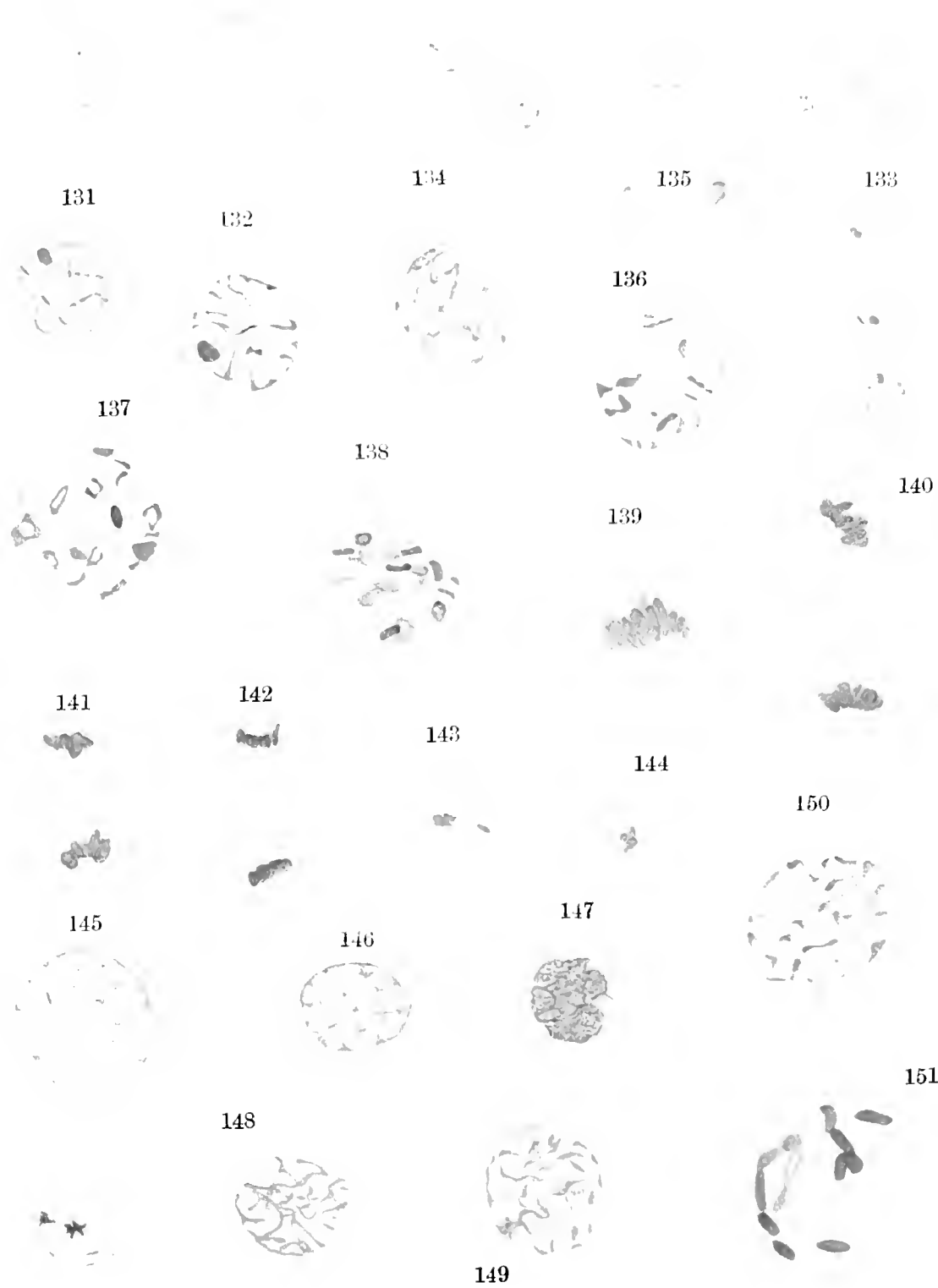
Plate X.

Studies in the Effect of Röntgen Rays upon the Development of Vicia faba[1].

By

Hideo Komuro.

With Plates XI-XII and one Text-figure.

CONTENTS.

1. Introduction.
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5. Discussion.

I. Introduction.

From the experiments carried out during a period extending from March 1917 to April 1922 with interruption of some months the writer obtained the following new facts besides several other results. Strongly irradiated seeds in air-dried and steeped condition do not stop their development immediately, they germinate and develop for a certain period. Sprouts from irradiated steeped seeds containing much water do not appear above the soil and their development ceases at almost the same stage of growth under the ground irrespective of doses given. When the dose of Röntgen rays exceeds a certain limit, no difference is seen in the state of impediment proportional to the dose and their effect is no more than an injurious stimulation to the seeds.

From the above results the writer presumes that strongly irradiated seeds

1. The present work was carried out by a grant from the Morimura Hômei Kwai. The main part of this paper was read before two meetings of the "Tôkyô Igakkwai" (Tôkyô Medical Society) on Nov. 5, 1917, and on Oct. 6, 1919, incorporating the results of germination-experiments which were made during June, 1919, and published in Japanese in the "Irigaku Ryôhô Zasshi" (1918), the Tôkyô Botanical Magazine (1919 and 1920) and in the "Keiô Igaku" (1921).

are particularly affected at the plumule and the radicle. The metabolism of these parts may be so gradually modified that at a certain stage the seedlings cease to develop.

II. Historical Survey of the Effect of Röntgen Rays
upon Higher Plants.

RÖNTGEN discovered the X-rays in 1895 and two years after this discovery LOPRIORE for the first time studied their effect upon plants. Since then about thirteen investigators have been engaged in the study of this problem. Now the writer will shortly review these results in periodical order.

LOPRIORE (1897) observed the fact that pollen-germination of *Genista* and *Darlingtonia coronillæfolia* was suppressed by X-rays.

MALDINEY & THOUVENIN (1898) experimented on the effect of Röntgen rays upon *Calystegia sepium* and *Oenanthe stolonifera* and found that germination and growth were accelerated, but there was no effect on chlorophyll formation.

SECKT (1902) stated that the acceleration of the protoplasmic movement in the hair cells of *Tradescantia* and *Cucurbita* by irradiation is similar to the effect of toxic substances and wound-stimulus on plant cells, and the effect of X-rays differs according to the distance between the tube focus and the material to be irradiated and the time of exposure.

KOERNICKE (1904) exposed *Vicia faba*, *Vicia sativa* and *Brassica napus* to rays of 20 H-26 H — the material was young plants and air-dried and steeped seeds (3 days' steeping)—and observed an impediment of growth except in *Brassica*. There was no change at the time of irradiation, but the acceleration as well as the impediment of growth appeared only after some time had elapsed. These special after-effects (Nachwirkung) are due to the state of the material and its physiological condition at the moment of irradiation. *Brassica* may have a resistance against the effect of X-rays; there appeared no conspicuous impediment of growth from a dose by which the growth of *Vicia faba* was obstructed severely. In the case of a not too strong irradiation, an impediment may temporarily appear, as the radicle, whose growth was thereby stunted for a time, begins to develop again. Increase of germinating power of air-dried seeds was not observed as in the case of steeped seeds— the experiment was repeated twice with the former dose of 20 H.

GOTTWALD SCHWARZ (1907) investigated the relation between the grade of metabolism and the sensibility to Röntgen rays upon *Avena sativa* and *Vicia faba*. The grade of metabolism in dried seeds is in minimum degree, so the seeds are in the resting state; but if they are put into water, they soon begin to metabolize and the radicle and plumule sprout from the embryo. Such dried seeds were exposed by him to rays of 200 H and sown. The 200 H-plants developed as well as the unirradiated controls and there was no difference between them.

But *Avena sativa* of 2 days steeping, divided into two parts, one half taken as control and the other half exposed to the rays of 6 H and placed in a dish (in water), showed during the first 3 days no difference between the control and 6 H-seeds, but on the fourth day the latter appeared in a special state and on the eighth day the 6H-seedlings were only one-third of the length of the control. He observed this relation also in *Vicia faba* and concluded that "die Röntgenlichtempfindlichkeit der Zellen ist ihrer Stoff-wechselgröße gerade proportional". Moreover, he stated under the heading 'Vergleich der Röntgenwirkung mit der Lichtwirkung auf die Pflanze', in a supplement to his paper, that "wachstumhemmend und chlorophyllbildend wirken also die kurzwelligen ultravioletten Strahlen. Die Röntgenstrahlen reihen sich hier an. Physiologisch hat die Ultraviolettwirkung auf die Haut große Ähnlichkeit mit der Röntgenwirkung auf dieselbe.—Aus den vorstehenden Ver-suchen ergibt sich nun ein weiterer Parallelismus zwischen diesen Strahlenarten. Auch pflanzenphysiologisch verhielten sich die Röntgenstrahlen im Wesen den ultravioletten Lichtstrahlen analog"[1].

SCHMIDT (1910) steeped the seeds of sweet peas for 6 hours, exposed them to the rays of $\frac{1}{4}$ H, $\frac{1}{2}$ H, 1.25 H, 2.5 H and 5 H, and put them into the soil. The former four groups developed better than the control and the 5 H, and bore many fruits. Further, 5 seedlings (ca. 2 cm.), which had been germinated in the soil, were used and 1 H was given to the middle, 10 H to the left and 20 H to the right hand side of the row, then the seedlings were again planted into the soil. At the end of this experiment, the 10 H- and 20 H-plants reached only 5 cm. in shoot-length, but the other three reached 10–15 cm.

1. Mitteilungen aus dem Laboratorium für radiologische Diagnostik und Therapie, Bd. 1, Heft 2, 1907. pp. 93-95.

He recognized the practicability of X-rays, based on this positive stimulus by weak irradiation, and found an acceleration of growth.

WETTERER (1913) divided seeds of *Helianthus annuus*, which had been steeped in water for 3 days, into five parts, one of which was taken as the control and the rest exposed to the rays of 5 H, 10 H, 20 H, and 40 H. Then they were sown in a rich soil. The control, 5 H- and 10 H-plants sprouted almost at the same time, the 20 H-plants came out later and crooked. Of the 40 H-seeds none germinated.[1] Compared with the control, the 5 H-, 10 H- and 20 H-plants showed an inferior growth proportional to the increase of the dose. He cropped the seeds from the 20 H-plants as well as the control and sowed them in soil in the beginning of the next summer (Frühsommer). From the control seeds, stout plants developed, but from the 20 H-seeds shorter and worse developed plants than the control were obtained, yet they were better than the mother plants, from which the seeds were derived. The second generation of the irradiated plants, which were impeded in their earlier development was worse in growth, but the impediment was less than in the first generation. The seeds cropped from these plants were sown out next year, the resulting plants had the normal form and height, and there was no change. Thus, he concluded that the effects of Röntgen rays do not appear in the third generation. According to the results of his experiments, the state of impediment in the same irradiated material is proportional to the doses given.

ERWIN SCHWARZ (1913) made experiments in order to find: 'wo lag das Optimum jener Strahlenmenge, die wir für die Reizwirkung brauchten?' and 'in welchem Stadium der Entwicklung der Reiz einsetzen müßte, wenn er in günstiger Weise zur Geltung kommen sollte', and he said "daß es mir nur dann gelang, eine Wachstumsbeschleunigung zu erzielen, wenn ich Samen vor der Auskeimung oder ganz junge, eben ausgekeimte Triebe bestrahlte, während es sich trotz aller möglichen Versuchsanordnungen als unmöglich erwies, ältere, bereits heranwachsende Pflanzen zu beschleunigtem Wachstum anzuregen". The writer gives here the results of his experiments. He irradiated dried seeds of *Vicia faba* as in the following table, and compared the length

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1. The writer presumes that by "nicht aufgehen" the author means that the plumule did not come out on the surface of the soil.

of shoot as to the difference of influence caused by the irradiation. (The irradiated seeds were sown in a soil, 3 grains to a pot, all placed near the window.)

No. of pot	Time of exposure	Length of shoot (cm.) (after 3 weeks)
I	Control.	24.5
II	30 sec.	20.0
III	90 ,,	11.0
IV	1 min.	11.0
V	2.5 ,,	54.0
VI	5 ,,	2.0 3.0

As the table shows, the plants grown from the seeds irradiated for 2.5 minutes were best in growth—2.5 minutes' exposure is equal to $\frac{1}{24}$ H, because scarcely $\frac{1}{2}$ H was given by continuous irradiation of 30 minutes—so he considered that $\frac{1}{24}$ H was the minimum dose for the growth to be affected positively. Next he avoided chance weak irradiation of vigorous seedlings, they develop better as a natural consequence. He wished to make researches on the effect of X-rays upon germinated seeds, so he chose the seedlings of *Vicia faba* which had previously been germinated in a thermostat, and irradiated them to such a degree that the most vigorous one was the weakest and the weakest or the one without sprout was the strongest. Then they were planted out at the same depth.

No. of pot	State of seedlings	Time of exposure (seconds)	Length of shoot 3 weeks after, in cm.
I	strongest, long sprout	Control	25.0
II	somewhat weaker sprout	30	40.0
III	still weaker sprout	60	42.5
IV	very weak sprout	120	43.5
V	very small or without sprout	240	37.0

After 6 days the sprouts of seedlings Nos. III and IV appeared above the surface of the soil, the latter of the two was better in growth and one of the shoots reached 1 cm. The length of shoot is tabulated above. So he said : " es werden demnach die Bohnen, die sich gegenüber den anderen durch eine gewisse Keimträgheit kennzeichnen, durch die Bestrahlung derart angeregt, daß sie

die sich normal entwickelnden weit überholen". 'How long does the stimu-
lation continue after irradiation?' was tested on the dried seeds of *Vicia
faba*. The seeds were exposed to the rays for 60 and 200 seconds, immediately
separated and put in envelopes. Then they were sown 4 and 8 weeks after
irradiation. From the results of these experiments he concluded that, "der
durch die Röntgenbestrahlung gesetzte Wachstumsreiz scheint demnach für
eine bestimmte Zeit im Keime zu ruhen und dann noch in ziemlich unver-
änderter Kraft zur Geltung zu kommen, wenn dieser nach Wochen ausgesät
wird. Mit zunehmender Dauer des Latenzstadiums geht jedoch die Reiz-
wirkung mehr und mehr verloren. Diese Ergebnisse ähneln in gewisser
Hinsicht den von WETTERER mitgeteilten, wenn dieser die durch intensive
Bestrahlung erzeugte Wachstumshemmung noch bis in die 2. Generation
verfolgen konnte".

KOERNICKE (1915) who had experimented in 1904 on the effect of the
rays upon *Brassica napus*, *Vicia faba* and *Vicia sativa*, now used the following
plants: *Vicia faba*, *Phaseolus multiflorus*, *P. vulgaris*, *Lupinus albus*, *Brassica
napus*, *Sinapis arvensis*, *Papaver somniferum*, *Zea mays*, *Triticum vulgare*
and *Avena sativa*. He experimented to find out if the Röntgen-culture is
possible. The results of his researches are closely connected with those
of mine, and, therefore, the writer proposes to give a rather detailed abst-
ract. KOERNICKE repeated the conclusion of his former experiments: "Rönt-
gen- und ähnlich auch die Radiumstrahlen wirken in genügend starker
Intensität hemmend auf das Wachstum ein. Nach der Bestrahlung ist zunächst
nichts von einer derartigen Hemmung zu bemerken, ja es tritt zunächst meist
eine Wachstumsbeschleunigung zutage. Die Hemmung folgt vielmehr erst
einige Zeit nach der Bestrahlung. Der Zeitpunkt des Eintretens dieser eigen-
artigen Nachwirkung ist von dem Objekt und seinem physiologischen Zustand
im Moment der Bestrahlung abhängig. Ist die Intensität der Bestrahlung
nicht stark genug gewesen, so bleibt die Wachstumshemmung nur eine
vorübergehende", and he stated anew that, "die verschiedenen Pflanzenarten
zeigten oft starke Unterschiede in ihrer Sensibilität den Strahlen gegenüber.
Jedenfalls sind manche Abweichungen in den Versuchsresultaten auf die
geringe Kontrollmöglichkeit der jeweils zur Wirkung gebrachten Strahlungs-
intensitäten zurückzuführen". The methods of his experiments were: the

material used for irradiation was (1) air-dried seeds ("trockene, ruhende Samen"), (2), one day, two days and a few days' water-steeped seeds, (3) those with radicles, and (4) seedlings which previously had been germinated in the pot and were in the same state of growth, and their development was observed. The doses given were in the first experiment of ten kinds, $i.e.$, 5 H, 3.5 H, 2.5 H, 1.5 H, $\frac{1}{2}$ H, $\frac{1}{10}$ H, $\frac{1}{20}$ H, $\frac{1}{10}$ H, $\frac{1}{60}$ H, and $\frac{1}{100}$ H. In the other case, strong irradiation was employed. 220–3,000 grains of seeds were used in every experiment, sown into a pot containing wet poplar saw-dust after the irradiation and planted in open ground after their first development. He said that, "von den Versuchspflanzen wies eine sichtliche Beeinflussung des Wachstums durch die Röntgenstrahlen eigentlich nur $Vicia$ $faba$ auf. Betreffs der Keimung zeigten allerdings die übrigen Versuchspflanzen, außer den Getreidearten, bei welchen überhaupt keine Wirkung zu erkennen war, analoge Verhältnisse wie $Vicia$ $faba$, wenn auch in schwächerem Maße". The results of experiments were, (1) in the case of air-dried seeds: the strongly irradiated germinated generally sooner than the weakly or unirradiated. At first there was a difference in growth, but they were balanced in the flowering time, (2) in the case of steeped seeds; the one or two days steeped gave the same results as those under (1), in three days steeped seeds, the growth of 3.5 H- and 5 H-plants was impeded a little at first—there was a difference proportional to the doses given—but afterwards it was balanced, (3) in the case of the seeds with radicles, the growth of 1.5 H was at first inferior. But the growth of $\frac{1}{60}$ H – $\frac{1}{20}$ H seedlings was accelerated. A part of these materials showed marked differences at first, but afterwards they were perfectly balanced and in the flowering time these plants showed a similar state of development to the 5 H-plants which were somewhat slender. Then he said, supporting E. SCHWARZ's statement, that "an den bereits im vorgerückten Keimungszustand bestrahlten Pflanzen war von einer Förderung des Wachstums, auch nach Applizierung der schwächeren Dosen, nichts zu bemerken. Bei den Dosen von 3X (=1.5 H) an aufwärts fiel dagegen besonders stark der schädigende Einfluß auf: die Pflänzchen blieben bald entsprechend der Intensität der erhaltenen Dosis in ihrer Entwicklung zurück". When four weeks had passed after the irradiation, the 5 H-plants did not make any further growth. The 1.5 H-, 2.5 H- and 3.5 H-plants ceased to grow proportional to the doses given.

He formulated G. Schwarz's conclusion in other words, surveying the results of his experiments: "die verschiedenen Pflanzenarten besitzen eine verschiedene Röntgenempfindlichkeit; je reger die Lebenserscheinungen in einem Organismus von statten gehen, desto stärker und eher macht sich der Einfluß der Bestrahlung geltend". He recognized an acceleration of growth only when air-dried and germinated seeds had been irradiated, but the growth could not be accelerated at all by the strong irradiation which E, Schwarz gave. E. Schwarz exposed air-dried seeds to the rays of $\frac{1}{12}$ H and observed a marked impediment of growth, but in Koernicke's experiments this small dose caused no effect upon them, and an impediment of growth appeared first at above 50 H. He stated on the impossibility of Röntgenculture: "mit der Feststellung der Tatsache, daß die meisten der zu den Versuchen herangezogenen Samen von Kulturpflanzen so wenig röntgenempfindlich sind, dazu bei der am meisten röntgenempfindlichen dicken Bohne die Sensibilität je nach der Sorte und bis zu einem gewissen Grade auch bei jedem Individuum innerhalb der Sorte schwanken kann, ist die Aussicht auf eine praktische Verwendbarkeit der Röntgenstrahlen in der Landwirtschaft, wie sie sich in Anknüpfung an die Schwarzschen Untersuchungsresultate zunächst zu eröffnen schien, geschwunden". The interpretation of his experiments was that the size of experimental objects and the number and size of their single cells is in relation to their sensibility to X-rays, and stated thus: "bei der dicken Bohne (*Vicia faba*) zeigte sich eine Schädigung bei Intensitäten über 100 X (= 50 H); bei dem Mais (*Zea Mays*), dessen Körner beträchtlich geringeren Umfang besitzen, erst bei 250 X (= 125 H); die winzigen Mohnsamen (*Papaver somniferum*) schließlich keimten noch bei Dosierungen von 500 X (= 250 H) fast ungeschwächt". He concluded that "in ihrer Wirkung auf den pflanzlichen Organismus lassen sich die Röntgenstrahlen mit anderen Strahlungen in Parallele stellen, die in stärkerer Intensität einen wachstumshemmenden Einfluß ausüben, ja direkt schädigen, in schwächerer jedoch wachstumsanregend, bezw. -beschleunigend wirken können und so sich ähnlich verhalten wie andere in stärkerer Applizierung dem Pflanzenleben schädliche Agentien, z. B. Verletzung, vor allem Gifte, deren wachstumsstimulierende Wirkung bei schwächeren Dosen gerade jetzt wieder Untersuchung erfährt".

CASIMIR exposed the seedlings of *Vicia faba* to the rays of 200 H and investigated cytologically. According to the description of J. WETTERER,[1] CASIMIR's result was as follows: —" Als Resultat der Bestrahlung ergab sich, daß in dem Keimling die Zell- und Kernteilung völlig zum Stillstand gelangt war. Am deutlichsten traten Zerfallserscheinungen am Zellkern auf, bestehend in Karyorhexis und Karyolysis. Die enorme Dosis hatte so prompt auf die lebhaft proliferierenden Zellen der Keimlinge gewirkt, daß der Kernteilungs- prozeß sofort inhibiert war ".

The writer (1916) made a cytological investigation on *Vicia faba* exposed to the rays of 5 H, 10 H, 20 H, 40 H, 60 H and 80 H. The results obtained were as follows: in the preparations of 5 H–20 H, there appeared no difference compared with the control, in the 40 H preparations, more mitotic figures were found than in the case of others, and the chromosomes seemed to become somewhat thick and short compared with the control, but there was no change in the division figures, and the stage of anaphase and telophase were found frequently in each preparation, and in the preparations of 80 H the nuclei were more or less degenerated, the outline of the nuclear membrane being scarcely visible. In such cells, the cytoplasm was filled with large vacuoles. The starch grains in the root cap (and the lower part of the periblem) were found to have changed in size and were more scattered in the cell. The writer observed that the chromosomes assumed an irregular arrangement and became more or less slender in the metaphase, and the stage of anaphase and telophase were very rare and were found in an abnormal state.

YAMADA (1917) reported the results of the culture-experiment on *Oryza sativa* exposed to the rays. He used " Takenari ", an aquatic race of *Oryza sativa*, for his experiments and irradiated them as follows:—

No.	Dose	Time of exposure (minutes)
I	3 H	10
II	5 H	16
III	7 H	22
IV	10 H	30

1. WETTERER, J. Handbuch der Röntgentherapie, 1. Bd. pp. 299–300.

Before the irradiation, he steeped the grains in salt water to select them, and then steeped them in water for 168 hours (7 days). He placed them flat in a porcelain dish after leaving them 4 hours out of the water, and irradiated with the above doses. Then they were again steeped in water 2 hours after irradiation and sowed in a paddy soil, one grain for one stock, 48 hours after irradiation. His results were: an acceleration of germination was not observed, the growth of the irradiated plants was at first inferior to the controls, but later the growth of 3 H-plants became the best, and the number of tillers was larger than in the others. The 7 H- and 10 H-plants were damaged by insects and fungous disease, and the crop was decreased by these obstructions. The 3 H-plants showed 40% increase in the amount of crop. According to the results of the cropping of a limited area (one "tsubo"), the 3 H- and 5 H-plants showed 8.3% and 2.9% increase of crop, and the 7 H- and 10 H-plants 2.4% and 5.4% decrease of crop (this might be caused partly because of the damage by insects and disease), i.e., the 3 H- and 5 H-plants gave better results than the controls.

NAKAMURA (1918) published the results of culture-experiments of *Oryza sativa* ("Sinriki"), of which grains were exposed to X-rays for 5, 10 and 15 minutes after steeping in salt water and then cultivated in a paddy soil. He reported that the plants grown from seeds with 5 minutes' exposure showed an increase in the amount of crop.

The writer's results (1919) of germination-experiments with *Oryza sativa* ("Sekiyama")[1] showed an acceleration of germination, and that of seeds irradiated in air-dried condition was more manifest than that of irradiated seeds after 12 hours steeping. For air-dried grains with a water content of ca. 8%, 5 H-10 H was the optimum dose for acceleration.

From the writer's experiments (1922) of cultivation of air-dried and steeped irradiated plants of *Oryza sativa* ("Sekiyama") in WAGNER's pots and on a paddy soil in 1919 and 1920, it will be seen that the amount of crop in *Oryza sativa* is not at all increased by the irradiation of X-rays. The only change produced by irradiation was precocious growth; young plants reached the stage at which they can be transplanted earlier than the control.

The writer (1922) made a cytological investigation on the root-tips of

1. "Sekiyama" is one of the pure lines of an aquatic race of *Oryza sativa*.

Vicia faba, "Hyôgo", grown from irradiated seeds. The cells of the radicle of the 50H irradiated seeds showed changes, such as formation of multinucleated cells, enlargement of both the cell and the nucleus, vacuolization of both the nucleolus and the cytoplasm, increase of the number of nucleoli and decrease of chromatic substance. Mitoses are very seldom met with and almost all cases were anomalous, the chromosomes having become fragmentary and scattered in the cytoplasm, and mechanical tissues developed, while in the controls he could find numerous mitotic figures, no differentiation of mechanical tissues having taken place. In the periblem tissue many cells are found in karyolytic condition and others in pyknosis. Even in the tissue adjacent to the growing point pyknotic cells are found. It is interesting to find, that these changes resemble those of tumor cells (especially in the testis-carcinom of the horse). It may safely be said that irradiation of X-rays (large dose) upon the seeds of *Vicia faba* leads the cells of radicles to a diseased or senescent condition resembling that of tumor cells.

The results of the above mentioned authors can be summed up as follows:—

1. Röntgen rays have a harmful effect on the seeds proportional to the water contents of seeds.

2. The seeds, which are late in germinating, as *Vicia faba*, were stimulated by Röntgen rays. The germination of *Calystegia hederacea*, *Oenanthe stolonifera* and *Oryza sativa* was accelarated.

3. To irradiate the seeds with a moderate dose before sowing gave good results for the growth of the plants *i. e.*, it became a positive stimulus.

4. The irradiation of younger plants does not produce any acceleration of growth and affects them rather harmfully proportional to the degree of dose.

5. The plants have different sensibility to Röntgen rays, *i. e.*, they show "selective absorption".

6. In weak irradiation, the harmfulness of the rays is proportional to their intensity.

7. Even if we expose seeds containing much water to a high dose of Röntgen rays, we cannot make the seeds stop their development immediately. They germinate and develop for a certain time.

8. According to the cytological observation of the tip of radicles from

the irradiated seeds of *Vicia faba*, there was no difference in the condition of cells compared with the control in weak irradiation; with a certain dose, there were rather many division figures, but after strong irradiation mitoses are very seldom met with and almost all cases were anomalous, the chromosomes having become slender or fragmentary and were scattered in the cytoplasm, and, moreover, the mitotic figure of anaphase and telophase was very rare and occasionally irregular. After a certain dose, the chromosomes became short and thick, the nuclear membrane somewhat irregular, and the chromatic substance increased or decreased very much. In other cases, changes were seen, such as multi-nucleated cells and others, resembling those of tumor cells.

9. From the cytological observation of young plants of *Vicia faba* irradiated with 200 H, the cell and nuclear division were entirely interrupted and the periphery of nuclei destroyed, some in karyolytic condition and others in karyorrhexis

III. Culture Experiments.

It was the wish of the writer to show by Experiments I–IV that an impediment of growth will occur with any of the doses given. E. Schwarz (1913) observed the apparent impediment by $\frac{1}{12}$ H on the seeds in a resting state (air-dried seeds of *Vicia faba*. M. Koernicke (1915) denied this and said that in air-dried seeds of *Vicia faba* the impediment appeared first at above 50 H, moreover, he reported that seeds on which the tip of the radicle appeared after many days steeping were severely impeded in their growth by 10 X(=5 H) and 15 X(=7.5 H).

G. Schwarz (1907) studied the relation between the sensibility to Röntgen rays and the water content of seeds, and said that the sensibility to Röntgen rays is proportional to the degree of the water content of irradiated cells, so the writer steeped the seeds in water for different lengths of time and determined their water content.

The seeds used for these experiments were " Sengoku-kurome ", a race of *Vicia faba* obtained from the Tôkyô Kônôen, the air-dried weight of which was 0.9 gr.

It was the great regret of the writer that he could not use more than 20 seeds for each dose, because the Röntgen tube used permitted only ca. $\pi 10^2$ cm.

area for effective exposure, and this area will only admit about 130 seeds swelled as the result of steeping.

Notice:—The following abbreviations are used in this paper for convenience: "Tube distance" means the distance between the Röntgen-ray tube-focus and the object to be irradiated, "Irradiated material" means the seeds and plants irradiated.

Irradiation[1] was made by KŌITI FUJINAMI at the Röntgen Laboratory of the Juntendô Hospital in Tôkyô. Tube distance was 15–30 cm. The Röntgen tube used was GIBA's water-cool tube with a hardness of BENOIST 6, and the current passing through it was 10 milliampères. To irradiate the seeds, they were placed flat in a porcelain dish (cuvette), and care was taken to irradiate uniformly in turning the seeds over and over again and changing their position as the tube was changed.

EXPERIMENT I.

The seeds were steeped in water for 46 hours prior to the experiments and exposed to the rays of 40 H, 50 H, 60 H, 80 H, 100 H, 120 H, 150 H when the water content reached 57.49%, on March 17, 1917. 21 hours after irradiation they were sown on March 18 in the field, one grain for one stock, the distance between the rows of field was 2 $syaku$[2] and the distance between the plants was 1 $syaku$. The writer was permitted to use Marquis YOSITIKA TOKUGAWA's field at Fujimi-Chô, Azabu, Tôkyô, for which favour he expresses his hearty thanks. The field consisted of clay soil, and the former crops were *Brassica campestris* L. var. (mikawasima-na), *Solanum meloxgena* L. in 1915 and *Arachis hypogea* L. in 1914.

The manure given was 5 gr. of calcium superphosphate and ca. 140 gr. of stable manure to each stock.

The experiment extended from March 19 to May 10, 1917.

Ten seeds of each group were sown with the same number of unirradiated controls, surrounded by two extra rows in the same distance of rows and plants. This care was taken to minimize the special effect of surroundings.

The results of this experiment are tabulated below.

1. The writer expresses his hearty thanks to Mr. MATSUDAIRA for his kindly help in the irradiation.

2. $syaku$ = 0.30 m.

TABLE I.

Dose	State of underground (May 10)	
	No. of seedlings	No. of dead seedlings
40 H	2	
50 H	1	1
60 H	1	1
80 H	5	
100 H	1	1
120 H	1	1
150 H	3	2

Control:—Of 10 seeds 8 developed into plants about 20 cm in length.

As Fig. 1 shows, the irradiated seeds, whose sprout did not appear on the surface of the soil, germinated, and, moreover, they were of almost the same size and most of them were dead, but of the rather strongly irradiated ones many remained. The middle of 150 H-seedlings in Fig. 1 remained healthy up to the end of the experiment (May 10). It is proved by the aftermentioned culture and germination experiments that seeds containing more than 50% water, when the dose of X-rays exceeds a certain limit, will be affected only to an injurious stimulation. That many strongly irradiated seeds remain, may be due to the fact, according to the writer's supposition, that the strongly irradiated take a much longer time to develop to a state where the growth ceases, the weakly irradiated may reach this state sooner than the former.

EXPERIMENT II.

In the second experiment, the writer modified the mode of cultivation and used a different kind of soil. Special wooden frames were made instead of large pots, which were 6 *syaku* long, 1 *syaku* wide and 1 *syaku* high.

5 of these frames were placed on the ground and the same quantity of humus was filled in each. Seven irradiated seeds which came from the same batch used for the first experiment were used. They were sown with controls on a straight line in the middle of the frame, with intervals of 5 *sun*[1] and two

1.   *sun* = 3.03 cm.

extra seeds were sown on both sides, in the same intervals. Besides, two sets of 7 *sun* pots were prepared for the rest and seeds sown in respectively. When this was done, 17 hours had elapsed from the end of the irradiation

One can keep environmental conditions fairly constant when sowing the seeds in a limited place, and thus the frame was constructed instead of the pots.

Manure given was the same as in Experiment I. The experiment extended from March 10 to May 22, and during this period rainy days were rare, so the frame and pot were watered every day.

The results of this experiment are tabulated below.

TABLE II.

Dose.	No. of seeds.	State on May 4 (18 days after sowing)		State on May 22 (66 days after sowing)		
		No. of sprouted seedlings	Length of shoot	No. of dead seedlings	No. of plants	No. of rotted seeds
40 H	7	3	Vis.– 11.0		1	1
50 H	..	4	,, – 1.5	1		4
60 H	..	1	0.5	2		1
80 H	,,	3	,,	3		2
10.0 H	..	1	Vis.	2		1
120 H	,,	3	Vis. – 0.9 – 1.3	3		2
150 H	,,	2	Vis. – 1.2	4		1
Control.	,,	7	11.0		7	

In the table, the writer used "vis." (visible) to indicate the length of shoot. It means a very small sprout which scarcely came above the surface of the soil. In this experiment, the irradiated material sprouted on the soil, while none sprouted in Experiment I, so the writer tabulates the length of shoot to indicate the degree of sprouting, he wished by no means to compare by this length the difference of growth proportional to the doses given. One of the 40 H-plants developed as well as the unirradiated control plants and showed a length of shoot of 36.5 cm. at the end of the experiment.

As is clearly shown in Fig. 2, the plants ceased to grow at almost the same state as in Experiment I, this may be explained by the above stated

assumption of the writer, that of strongly irradiated seeds more remained, except one of the 40H-plants.

The seeds used in Experiments I and II were irradiated at the same time and separated into two parts, one was used for field culture and the other for pot culture. Of these seeds, whose water content reached 57.49% by 46 hours' steeping, the majority of the 40H showed the tip of the radicle to appear out of the seed coat; they also swelled very much compared with the others.

Experiment III.

The seeds were steeped in water for 31 hours (when the water content reached 50.08%) and exposed to the rays of 20H, 30H, 50H, 60H, 80H, 100H, 120H and 155H on March 31, 1917. Of 20 seeds of each group 18 seeds were used for this experiment and the rest for Experiment IV. The field used was one of the College of Agriculture, Imperial University, Tôkyô. The soil of the field consisted of humus, and the former crop was *Arachis hypogaea* L. The irradiated seeds were sown with the controls and extra seeds, as in the former case, and 3 gr. of calcium superphosphate and ca. 100 gr. of stable manure were previously given. The experiment extended from April 1 to June 16 in 1917.

The results of this experiment are tabulated in Table III, and shown in Textfig. 1 and Figs. 3 – 5.

As the table and figures show, the 20H-plants developed better in the field than the controls and other irradiated plants, and the 40H-plants ranked next to the 20H. 16 of 18 seeds of the 20H and 30H germinated and grew, and the other irradiated seeds decreased in the number of germinations proportional to the increase of the dose. None of the 155H sprouted, but they germinated under the ground and developed to the state shown in Fig. 6.

The dry weight of the plants, whose growth in the field was better, was heavier than that of the others, as Table 3 shows (refer to the curve).

The experimental plants were attacked by *Pipistrillus abramus* since the middle of May, and there were plants which became impeded in growth and died, and, moreover, they were so severely injured that the flowers died before bearing fruits. This damage may have been caused by the unsuitable time

TABLE III.

Dose	No. of sprouted plants	State at the end of the experiment (June 16)	
		No. of plants	Average weight gr.
Control.	18	18	7.055
20 H	16	15	9.617
30 H	16	11	1.707
40 H	8	8	6.133
50 H	7	5	1.560
60 H	3	3	3.779
80 H	2	2	2.205
100 H	1	—	—
120 H	1	1	0.850
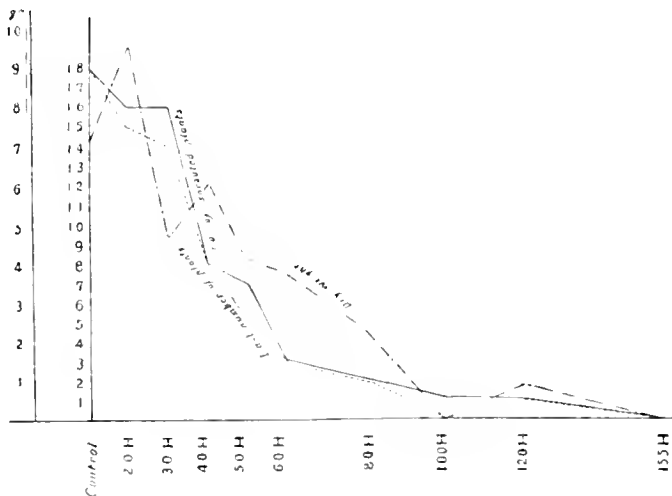
of cultivation, because *Vicia faba* must be sown in the middle or the end of October, but in this experiment it was sown on April 1, so the time was not fit for natural growth. But the writer supposed that it might be caused, on the one hand, by soil-sickness (Boden-Müdigkeit), due to the continuous cultivation of leguminous plants (for the former crop was pea-nut).

Conditions were as above mentioned, so the writer gave up the experiment

on June 16. Had he left the plants in the field, they would have been killed by *Pipistrillus*, and an observation of the results would anyhow have become impossible. He rooted up the plants, collected the fallen leaves of each plant, and determined the dry weight of each group (dessicated by a water-bath and dessicator), and intended to compare the differences of effect.

One or two exceptionally stout seeds, whose irradiation was above 80 H, developed to a plant, but the majority did not sprout at all, and no 155 H-plants came out on the surface of the soil. The dose above 50 H seemed to cause an injurious stimulation for the seeds whose water content was 50%. The 100 H-plant died before the last observation.

Experiment IV.

This was the water culture by KNOP's solution, but only two seeds for each group were used for trial, because of want of equipments. The principal object of this experiment was to observe to what degree the plants will develop, whose sprouts do not appear above the surface of the soil.

Two seeds of control, 20 H, 30 H, 40 H, 50 H, 60 H, 80 H, 100 H, 120 H 155 H were sown in a large pot containing saw-dust on April 2, 1917. The seedlings of each group were brought into KNOP's solution on April 9. Fig. 6 is the state on April 16, the 7th day after the treatment. 50 H-seedlings (for the wound) and seedlings above 80 H did not develop more than the state shown in Fig. 6. Fig. 7 is a photograph taken on May 4, and Fig. 8 on June 16 (at the end of the experiment). These plants were placed in the cold green house of our Institute. On May 29, the writer found the parasite of *Bacillus Fabae* UYEDA on the leaves of the 40 H-plant, so he pinched off 7 leaves. Afterwards, the plants of each group were attacked by *Pipistrillus abramus* and 0.3% solution of "Katakilla" was often coated on with a brush.

When the writer put the results of Experiments III and IV together, he came to the conclusion that except the exceptionally stout individuals irradiated material seems to have been impeded in growth generally at 60 H up, and these plants ceased to grow after a certain time. That is, these unsprouted ones germinated and developed equally for a certain period underground, and even the seeds exposed to the rays of 155 H did not cease their development at once but developed to a certain period as shown in Fig. 6.

In the seeds, whose water content was 50% (31 hours' steeping), there were creases on the seed coat, of course before the irradiation, at the time of sowing, 17 hours after the end of the irradiation, and the writer saw no conspicuous changes in 40H-seeds, as in the case of the seeds whose water content was 57.5% (46 hours steeping) refer to P. 270.

Anatomical Observation of the Leaf.

Using the leaves of plants of Experiment III, the anatomical differences of the mesophyll of each group were observed, but there was no difference among these. But the attention of the writer was attracted by the fact that the quantity of chlorophyll of the 80 H- and 120 H-plants was less than that of the others, so that the appearance of those plants on the whole was yellowish compared with that of the control and the others. A 100 H-plant died before the observation.

The object of experiments from V to VII was to cultivate *Vicia faba* in the normal season and to compare with the results already stated which were obtained during the period extending from April to June under unsuitable environments for *Vicia faba*, and, on the other hand, the former experiments were repeated. Moreover, there was no experiment as to the effect of the rays upon the air-dried seeds in the former experiments, so the writer made it side by side.

Seeds of " Hyôgo " (1917–crop), a race of *Vicia faba*, were obtained from the farm of the College of Agriculture and used for these experiments. Unfortunately, the seeds were few in number, so the writer could not minimize the individual deviation of the weight of seeds, as in the former cases, but seeds with an air-dried weight of 0.97–1.07 gr. (average 1.02) were used for Experiments V and VI, and, in Experiment VII, seeds of 1.28 gr. (average) were used.

As to the irradiation, all the precautions were the same as in the former cases.

METHOD OF CULTIVATION.

The field used was that of the College of Agriculture, composed of humus. The distance between the rows was 2 *syaku* and the distance between plants 5 *sm*. Two rows (front and rear) and three rows (right and left) of seeds were sown for extra.

Manure : ca. 100 gr. of stable manure and 1 gr. of calcium superphosphate were given on Oct. 26, after levelling the field and 1.5 gr. of wood ash on the day of sowing (Oct. 29). On April 2, 1918, diluted human manure mixed with rice bran was given.

EXPERIMENT V.

This was extended during the period from Oct. 28, 1917 to June 22, 1918.

The seeds were steeped in water for 24 hours, and, when their water content reached 57.32%, they were exposed to the rays of 20H, 40H, 60H, 80H and 100H[1]. Then they were sown[2] on Oct. 29 in humus, on which the previous crop was *Polygonum orientale* L., 20 hours after irradiation.

Care was taken to avoid the partial richness of soil in the field. The weather during the period extending from the end of October to the beginning of December was unsuitable for germination. The dates and the number of germinations are tabulated below :—

TABLE IV.

Dose Day of sprouting	Control	20 H	40 H	60 H	100 H
11/Nov.	10	1			
12	12				
13	13	6			
14	8	5			
15	7	3			
16	6	2			

1. It took 90 minutes to get 100 H.

2   Control seeds were 60, double the number of the irradiated.

Dose Days of sprouting	Control	20 H	40 H	60 H	100 H
18	1	1	1		
20		3			
22		2		1	
24		1			
27					1
4 Dec.	2				
10/,		1			
?	1				
Total	69	28	1	1	1

As the table shows, it seems that the germination of irradiated seeds were not accelerated; it was, in fact, rather delayed. On Oct. 30, the writer took 1 or 3 seedlings carefully out of each group, which had not yet sprouted above the ground, and examined the state of growth under the ground. Though the tip of the radicle of strongly irradiated seeds appeared coloured brown and stumpy, as if somewhat injured, their cotyledon was vigorous. The control and 20 H-plants, on the contrary, were in the first stage of growth as young plants. According to this fact, strongly irradiated seeds may have been affected severely. The state of growth of 40 H up was almost the same and there was no difference in growth apparent proportional to the doses given.

On April 2, 1918, 56 control plants and 12 20H-plants remained and the ratio of the remainder at the flowering time (middle and end of April) is tabulated below:—

TABLE V.

Dose	Percentage of the sprouted	Percentage of the remainder to the sprouted
Control.	100.0	90.00
20 H	93.3	17.86
40 H	3.3	0
60 H	3.3	0
80 H	0	0
100 H	3.3	0

This Table is to be referred to Table VI.

TABLE VI.

Dose Day of bloom	Control	20 H
16 April	2	1
18	6	
19	8	1
20	6	
21	19	1
22		1
24	8	
25	3	1
Total	52	1

As Table VI shows, it is evident that the time of bloom of the 20 H-plants was not accelerated. The growth of 20 H was inferior to that of the controls. The damage by *Pipistrillus abramus* became manifest in the middle of May, the plants were severely stunted, but produced seeds see Figs. 9 and 10).

As aforesaid, in the case of the seeds whose water content was a little over 57%, only 20H-plants among the irradiated bore fruits, though their remainder was less, and, moreover, the growth inferior to that of the controls. Other irradiated plants did not sprout (with the exception of a few), and ceased to grow at almost the same stage. The sprouting of the irradiated seeds was not accelerated, nor the bloom, they were rather delayed.

EXPERIMENT VI.

The seeds were steeped in water for 34 hours and exposed to the rays of 10H, 20H, 30H, 40H and 50H[1], when the water content reached 63.57% on Oct. 28. 22 hours after irradiation they were sown in humus; 20 seeds of each group of irradiated seed and 40 grains as controls.

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1. It took 45 minutes to get 50H.

TABLE VII.

Days of sprouting \ Dose	Control	10 H	20 H	30 H
10 Nov.	1			
11	9			
12	5			
13	8	2		
14	9			
15	3	3		
16	2	2		
17	1	1	1	
18		3		
19	1	1		
20		2	1	
22				1
23			1	
27		2		
5 Dec.		1		
6	1			
Total	40	17	3	1

The day of sprouting and the number are tabulated in Table VII, no acceleration is seen in the irradiated seed.

On Nov. 30, the writer carefully lifted out 2 or 3 unsprouted seedlings for examination and observed that they were similar to those in Experiment V. In 20 H- and 30 H-plants, only exceptionally stout ones sprouted (3 and 1 in number). On April 2, 1918, scarcely any of the 20 H- and 30 H- plants existed and by the end of April all had died.

Only 10 H-plants developed together with the controls, but their growth was inferior to that of the latter. *Pipistrillus abramus* also attacked these plants and damaged them very much, but seeds were obtained from them (see Figs. 11 and 12 Plate XII).

The day of bloom is tabulated in Table VIII, which shows retardation of the flowering time in 10 H-plants, if compared with the controls.

TABLE VIII.

Day Dose of bloom.	Control	10 H
16 April	5	
17		
18	4	
19	3	
20	1	1
21	14	2
22	3	
24	6	3
25	1	
Total	37	6

TABLE IX.

Dose	Percentage of the sprouted	Percentage of the remainder to the sprouted
Control	100	92.50
10 H	85	35.29
20 H	15	0
30 H	5	0
40 H	0	0
50 H	0	0

Table IX shows the relation between the percentage of sprouted seeds to that of the remainder in flowering time (refer to Table VIII) and proves that the plants of 20 H upwards were injuriously affected. As above stated, the seeds having a water content of a little over 63% were stunted even by 10 H. As Tables VII and VIII show, it seems that there is no acceleration of sprouting and bloom, rather a retardation.

The common results of Experiments V and VI were as follows :—

1. According to the observation of unsprouted seedlings on Nov. 30, there was no difference in growth proportional to the doses given; the seeds had developed to almost the same stage, and the roots reached a length of ± 2.5 cm.; but they were injured at their tip and became stumpy, though their cotyledon was healthy (at this time, the controls and the weakly irradiated reached their first step of development as little plants).

2. The time of sprouting and bloom was not accelerated and both were rather delayed.

No observation was made for the crops of Experiments V and VI, as there was damage by *P. abramus* in addition to the effect of Röntgen rays.

EXPERIMENT VII.

This experiment was undertaken to see if are-dried seeds are affected by

the Röntgen rays. Schwarz (1907) reported that air-dried seeds of *Vicia faba*, exposed to the rays of 200 H developed just as well as the unirradiated controls. Koernicke (1915), on the contrary, states that there was impediment at 50 H and upwards in the case of air-dried seeds[1].

The writer repeated the same experiment, cultivating air-dried seeds[1] of "Hyôgo," whose water content was 13.75%, exposed to the rays of 40 H, 50 H, 60 H, 80 H and 150 H and sown out. On account of lack of seeds and space for sowing he could not use more than 10 seeds for each group of dose (with 20 controls); irradiation above 150 H were not tried for lack of time.

TABLE X.

Day of sprouting	Dose: Control	40 H	50 H	60 H	80 H
13 Nov.	1				
14	1				
15		2			
16	1		1		
17	7	2	1		
18	2	1			
19	1		1	1	
20	1	4	3	3	
21			1	1	
24	3		1		
25				1	
26				1	1
27				1	
3 Dec.			1	2	1
1		1			
One day of Jan. of '18					1
Total.	20	10	9	10	3

Table X shows the relation between the day and the number of sprouted

1. Koernicke uses the word "ruhende Samen" in his paper.
2. Average weight of them was 1.28 gr.

seeds. The day of sprouting is delayed proportional to the increase of dose, i.e., one of the 80 H-plants sprouted one day in January '18, but the 150 H-seeds did not sprout at all above the soil. But it was evidently seen even in their dead condition at the observation on April 2, 1918, that the 150 H-seeds had germinated and developed to seedlings, whose radicle reached 2 – 3 cm. under the ground.

TABLE XI.

Day of bloom \ Dose	Control	40 H	50 H	60 H	80 H
17/April.	1				
18	1				
19	1				
20	3				
21	10	5		1	
24		2	6		
25	1			2	
27	1			1	
28		1	3	2	1
30	1				1
2/May		2		1	1
3				1	
4				1	
Total.	19	10	9	9	3

As Table XI shows, the day of bloom is delayed proportional to the doses. Moreover, it is interesting to note that the day of sprouting and bloom is delayed rather more than in the two former experiments. The retardation of sprouting may be due to the difference of stimulus; the seeds having much water by steeping may have been more stimulated than the air-dried ones. If the sprouting is delayed, so will the growth, and thus a retardation of the time of bloom will naturally take place.

The relation between percentage of sprouted seeds and the remainder at the time of bloom is shown in Table XII, as well as the fullgrown plants.

TABLE XII.

Dose	Percentage of sprouted seed	Percentage of the remands to the sprouted
Control.	100	95
40 H	100	100
50	90	100
60 H	100	90
80 H	30	100
150 H	0	0

On April 2, the growth of 60 H-plants was somewhat inferior to that of controls, but in that of 50 H and down there was no difference in outward appearance. The growth of 80 H-plants was extraordinarily inferior. As aforesaid, 150 H-seeds germinated and developed to seedlings, whose radicle reached 2-3 cm.

In order to show the state of growth, the average of the number of nodes and nodes having buds is shown below :—

Subject of observation Dose	Control	40 H	50 H	60 H	80 H
No. of nodes	9.8	9.4	9.3	7.5	5.7
Nodes having buds	8.6	8.35	8.3	6.5	6.0

(Examined on April 6)

The inferior appearance of 60 H-plants on April 2, as aforesaid, is due to this decrease in the number of nodes. In the 80 H, the development was so bad that the average-number of nodes not only decreased, but only one of them had buds on April 6.

These plants were parasited by *Bacillus Fabae* but there was no damage by *P. abramus*. Therefore their growth was very good and their fruit was cropped[1] on June 22, '18.

1. On account of illness of the writer, his friend Mr. Y. IMAI gathered the crop and classified the fruits with Mr. K. KIMURA; he asked Mr. S. NAGAI to photograph them as shown in Figs. 9–14. Without this assistance, the results of experiments V–VII would have had to be abandoned. The writer expresses his hearty thanks to these gentlemen for their kindly help.

The number of branches bearing fruit of one plant, the number of seeds and their weight (weighed in the beginning of April, '19) are respectively tabulated below :—

No. of individual	No. of branches	No. of seeds	Air-dried weight (Gr.)	
1	4	23	35.00	
2	2	12	14.50	
3	4	23	29.00	
4	3	21	30.00	
5	4	18	13.00	
6	4	20	27.50	
7	4	22	27.00	
8	4	45	48.50	
9	5	55	57.50	Control plants
10	3	14	20.00	
11	3	21	32.50	
12	3	18	22.50	
13	4	25	36.00	
14	4	18[1]	27.50	
15	4	28	34.50	
16	2	16	16.50	
17	2	12	16.50	
Fig. 13 (left)	3	14	20.00	
Fig. 13 (right)	6	75	72.50	
1	5	24	26.00	
2	5	28	38.00	
3	4	22	22.00	
4	5	37	42.50	
5	4	17	21.50	40 H-plants
6	4	24	29.50	
7	5	25	41.50	
8	3	26	32.00	
9	4	11	12.00	
10	1	4	5.00	
2	4	21	31.00	
3	3	22	23.50	

1. Including four worm-eaten ones

No. of individual	No. of branches	No. of seeds	Air-dried weight (Gr.)	
4	3	10	16.50	
5	4	24	28.50	
6	4	19	25.00	50 H-plants
7	2	6	6.50	
8	3	20	25.00	
9	5	25	20.50	
10	2	11	16.50	
1	3	9	11.50	
3	4	16	17.50	
4	6	30	26.50	
5	2	5	7.50	60 H-plants
6	2	9	13.50	
7	3	25	28.50	
8	2	12	15.50	
9	3	13	12.50	
10	2	9	9.00	
4	4	12	13.50	80 H-plants
6	1	1	0.67	
9	1	2	2.00	

(Note to Fig. 16: Each little heap in this figure is the crop of one plant.)

A summary of the results is shown in Table XIII.

TABLE XIII.

Subj. of observ. \ Dose	Control	40	50 H	60 H	80 H
No. of plants	19	10	9	9	3
No. of branches having fruit	68	40	30	27	6
Sum of the grains of seeds	480	218	171	128	15
Total weight (gr.)	59.05	270.0	202.0	141.5	16.17

The amount of crop decreased proportional to the doses given, and apparently showed a negative stimulation of the rays. Here the writer can

not accept G. Schwarz's results, though the water content[1] of his seeds was
not known. That is, in the writer's experiment, even in the air-dried seeds,
if their water content be about 14%, they are affected, and the impediment
in growth obviously appeared at 80 H and up. The 80 H-plants were stunted
so badly that only 15 grains of seeds were obtained from 3 plants, i. e.,
only stout individuals developed so far that they bore fruit. But the 150 H-
seeds germinated and developed to seedlings, the radicle reaching 2–3 cm under
the ground. Thus the writer verified Koernicke's result.

IV.   Germination Experiments.

They were performed on the seeds of "Hyôgo," a race of *Vicia faba*
(1918-crop), in Experiments VIII and IX.

As to the irradiation for these two experiments, the same care was taken
as in the case of others; the only difference being that the tube distance
was 15 cm. in this case.

Experiment   VIII.

In order to see if the presence of a seed coat affects the sensibility to
Röntgen rays and if there is acceleration of germination in steeped irradiated
seeds, this germination experiment was performed. The seed coat of a part
of these seeds was peeled so as to uncover the plumule and radicle, and then
these peeled and unpeeled seeds were exposed to the rays of 20 H, 40 H and
50 H at the same time. The tip of the radicle of peeled seeds became brown
by the irradiation. They were sown 2 and $4\frac{1}{2}$ hours after irradiation in a
square pot, with washed sand, and divided into four compartments. The
same number of controls, as 20 H-, 40 H- and 50 H- seeds, peeled and unpeeled,
were placed in these four sections of the pot. The writer used two sets of
these pots, and placed them near a window on the south side of a corridor.
One can keep environmental conditions fairly constant in sowing them in a
pot, but can not do so in the field.

1.   Absolutely dried seeds by "water-bath" have no power of germination; the writer's
experiments of this kind by using the seeds of *Vicia faba, Oryza sativa* and *Phaseolus vulgaris*
gave always negative results, so the seeds (trockene Samen) of Schwarz may not have been of
such nature, and, perhaps may not have contained less water than air-dried seeds.

The seeds were irradiated on April 19, 1919 and sown in the evening of that day. The controls sprouted on April 26. The seedlings were photographed on April 27 (Fig. 17). The lower row represents those from peeled seeds. From this experiment it will be seen that,

1. No conspicuous difference was seen in the growth of seedlings irradiated in different doses.

2. The seedlings from irradiated seeds whether peeled or not, grew alike.

3. The tip of the radicles from irradiated seeds is stunted and harder than that of normal seedlings.

4. There is no acceleration of germination in irradiated seeds.

By this experiment the writer could verify the common results of several former experiments i. e. "the seedlings which do not appear above the soil cease to grow at almost the same stage, and there is no difference in growth proportional to the doses given".

Experiment IX.

In order to see if there is acceleration of germination in air-dried seeds irradiated weakly, the following experiment was performed.

If air-dried seeds, with a water content of 10.49% were exposed (June 25, 1919) to rays of 7 H, 10 H and 15 H[1]. $8\frac{1}{3}$ hours after irradiation they were steeped in water for 12 hours, and then sown in a square pot with washed sands, and divided into four compartments.

The writer recognized such a seedling as of perfect germination, the plumule of which protrudes from the seed coat, and examined the seedlings at 10.20 A.M. on June 30. The germination-percentage was as follows:—

Controls	60%
7 H	26.6%
10 H	46.6%
15 H	25.0%

That is, there is no acceleration of germination in the irradiated seeds. As Fig. 18 shows, they are in almost the same state of growth.

1. It took 18.5 minutes to get 15 H.

They were photographed immediately after examination, and then wrapped into wet paper in a box (for carrying). 30 minutes after again planted in the sands and their growth observed. The growth of 7 H- and 10 H-plants was better compared to the controls and the 15 H, but the writer could not measure their lengths, for rats damaged them all the night before the measurement. By this fact, it is supposed that 15 H may not cause a good stimulation in this case.

KOERNICKE states that the effects of X-rays upon *Vicia faba* differ according to their race. In the steeped irradiated seeds of "Sengoku-kurome," as aforesaid, 20 H-plants were best in growth and maximum in dry-weight compared with the controls and the other irradiated ones. These two results (Experiment III and IX) seem to contradict each other, but they can be explained by KOERNICKE's results or by the difference of environmental conditions.

EXPERIMENT X.

Seeds of "Wase-soramame," which had been steeped in water for a few days, so that the tips of the radicles appeared from the seed coat, were exposed to the rays for one hour and then sown in sands, one hour after irradiation, on April 27, 1922.

Half of them developed a little, the other half sprouted and the young shoots and roots reached $\pm 1.5 - 3.0$ cm.

The X-ray bulb used for this experiment was ÔKURA's water-cool tube after MÜLLER, the hardness of which was $\pm 10.5°$ WEHNELT. Spark length was 15 cm. and the tube current ± 2.5 milliampères. Tube distance 30 cm. The writer made the irradiation under the direct control of Dr. N. FUJI at the Röntgen laboratory of the Agricultural Experiment Station, Department of Agriculture and Commerce, Nisigahara, Tôkyô.

A water cell was inserted between the bulb and the seeds. The cell is made of two aluminium disks 0.3 mm. thick supported by brass rings of 1 cm. height and provided with two short brass tubes for the in- and outflow of water. This device was used to prevent the thermal factor entering into the experimentation. 10 minutes' exposure corresponds to 8 H of HOLZKNECHT's unit.

The steeped seeds in the condition stated above, were stunted severely by one hour's exposure (corresponds to 48 H).

V. Discussion.

Here, the writer intends to compare the results of other authors with his own and then to sum up his results.

E. Schwarz says that there is acceleration of growth by weak irradiation, but he converted the time of exposure into dose, *i. e.*, when $\frac{1}{2}$H is obtained by continuous exposure of 30 minutes, 5 minutes exposure gave $\frac{1}{2}$H, so that, by $2\frac{1}{2}$ minutes $\frac{1}{24}$H was obtained. In the strict meaning, these doses are questionable. By 5 minutes' exposure $\left(\frac{1}{12}H\right)$, air-dried seeds were severely stunted, according to his results, but this cannot be accepted from the author's results of experiment VII, that is, in the air-dried seeds, with a water content of 13.75%, 40 H-, 50 H-, 60 H- and 80 H-plants bore fruit, though the amount of the crop decreased proportionally to the doses. So the writer presumes that he gave much larger doses than he states.[1] He says nothing about the seeds used, on both the race and the weight; for *Vicia faba* has large individual deviations, so that special care must be taken. He seems to have used *Vicia faba* without these precautions, and, moreover, he sowed 3 in a pot respectively and placed them near the window, so the plants grew excessively, according to his text figure, and he measured the length as the difference in growth proportional to the doses given. The writer thinks that it is not good to draw such conclusions from so small a number of experiments without paying attention to the above considerations. If his results are compared with those of the writer (Experiment III), they become doubtful, *i. e.*, in the seeds with a water content of 50%, 20 H show a positive stimulation, and one which was irradiated by a dose of more than 20 H developed.

Koernicke sowed irradiated seedlings. This is not a good treatment for *Vicia faba*, because transplanting is harmful to the Leguminosæ, so the plants received two impediments, the rays and by external injury. Therefore, an

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1. Dr. Fujinami agrees with the writer's opinion.

impediment of growth will naturally take place, and it is not reasonable to conclude that his results are caused only by the effect of the rays. He exposed seeds with radicles about to shoot forth as the result of a few days' steeping, to rays of $10X$ ($=5$ H) and $15X(=7.5$ H), and observed a conspicuous impediment of growth 9 days after the irradiation, he gives illustrations in wood cuts in his paper of 1915 (Fig. 2). These results are also questionable compared with the above stated results of the writer.

G. SCHWARZ states that he cultivated dried seeds (trockene Samen) exposed to the rays of 20 H and observed no difference in growth compared to the unirradiated controls, but in the writer's experiments of air-dried seeds, with a water content of 13.75%, a conspicuous impediment appeared at 80 H (the sprouting percentage of 80 H-plants was only 30%, while that of the controls was 100%), and no 150 H-plants appeared above the soil. The amount of crop decreased proportional to the doses used. As the writer explained at the end of the statement to Experiment VII, it is to be presumed that the seeds used for his experiments must have been air-dried, not absolutely dried; for this latter method entirely deprives the seeds of germinating power. It is to be regretted, that he did not show the water content of the seeds.

SCHMIDT's experiments were few in number and seeds used, and one may presume from the photographs in his paper that he took no particular care as to the method of cultivation (to avoid the special effect of surroundings for the plants situated on the edges). So his experiments lack accuracy. Such an experiment is not good where the seedlings are exposed to the rays and then planted again into the soil, as transplanting is harmful to Leguminosæ.

The writer is rather inclined to believe that the increase of the amount of crop due to irradiation as described in the paper by YAMADA and NAKAMURA may not be a real one. (Had they taken more care in cultivating the plants, their results might agree with mine.)

The writer took great pains to get accurate results, heeding the faults in experimental methods of other investigators. As *Vicia faba* has no pure line, he could not use it in the present experiments but he used a special race of it and weighed the seeds for averaging their individual deviation, and special care was taken for avoiding the effect of surroundings to the edges.

The writer was specially interested in the relation between sensibility to Röntgen rays and the water content of seeds, so in the seeds their water content was determined. As already stated, other investigators also pay attention to this point. For example, G. SCHWARZ (1907) says, "die Röntgenlichtempfindlichkeit der Zellen ist ihrer Stoffwechselgröße grade proportional" (p. 972). When the amount of water is less, impediment appears only by a rather strong dose, and vice versa. This fact is also observed by KOERNICKE (1915) "auch der Plasmareichtum und Wassergehalt der Zellen muß bei der eventl. Lösung dieser Frage in Betracht gezogen werden" (p. 429). Therefore, SCHWARZ's result on the 200 H-seeds of *Vicia faba*, which developed just as the unirradiated controls did, is open to doubt. In KOERNICKE's experiment, an impediment of growth appears at 50 H in the case of air-dried seeds. The relation between sensibility to Röntgen rays and water content of seeds at the time of irradiation is important and of interest. But these authors did not indicate exactly the water content of the seeds used, so that their results cannot be directly compared with those of the writer.

KOERNICKE states that only *Vicia faba* among ten kinds of experimental plants was affected by X-rays, the others showed neither a positive nor a negative effect, and the germination of cereals, in particular, is not accelerated nor is there any effect in their growth, but the writer observed the acceleration of germination in *Oryza sativ a*[1] and *Phaseolus vulgaris*[2] (white seeded varieties). Therefore he cannot agree with him.

Plants differ in sensibility to Röntgen rays according to the species. In other words, plants make selective absorption. So the writer thinks the effect cannot be definitely stated as regards a certain plant, unless a large number of experiments have been made.

The following are the special results obtained from the writer's experiments :—

(1) Though the seeds are exposed to Röntgen rays of high dose, their development is not stopped immediately. They germinate and develop for a certain period.

(2) Though the impediment of growth is caused by the dose which is inversely proportional to the water content of seeds, the injured plants cease

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[1] In air-dried irradiated seeds, 5 H-10 H was the effective dose for acceleration.
[2] Of 5 H-, 10 H-seeds, the germination of the 5 H-seeds was accelerated.

to develop at almost the same stage of growth under the ground. There is no difference in growth proportional to the doses given (when the steeped seeds contain same amount of water by steeping).

(3) When the dose of Röntgen rays exceeds a certain limit, it does not induce a visible difference in the state of impediment proportional to the dose. The effect of Röntgen rays in these cases is no more than an injurious stimulation for the seeds—of course, this limit varies with the water contents of the seeds at the time of irradiation.

From these facts, the writer thinks it may be presumed that strongly irradiated seeds are particularly affected at the plumule and radicle, and metabolic change of these parts may take place, and when this change reaches a certain stage, the seedlings cease to develop.

NEUBERG's statement in his paper entitled " Beziehungen des Lebens zum Licht " may be of interest in this connection: " Das sind Reaktionen, die den Ablauf des Stoffwechsels in einer belichteten Zelle völlig ändern können. Da die Photokatalysen den Abbau hochmolekularer Substanzen, ähnlich wie Enzyme, besorgen, kann man sich vorstellen, daß bei darniederliegendem Stoffwechsel das Licht eine anregende Wirkung dadurch entfaltet, daß es in gewissen Sinne die Rolle von Fermenten übernimmt oder durch Bildung von anomalen und besonders reaktionsfähigen Spaltungsprodukten (Aldehyden, Ketosäuren u. dgl.) ungewöhnliche Reize ausübt " (p. 54).

A summary of the results of our experiments, in addition to the specially stated three facts, is as follows:—

(1) Though air-dried seeds with a water content of 10.5% were exposed to rays of 7H-15H, there occurred no acceleration of germination.

(2) Though air-dried seeds having ca. 14% water are exposed to rays of 40H and up and steeped seeds of 57% up to 10H, the day of sprouting and bloom is not accelerated, they are rather delayed according to the increase of the dose.

(3) The effect of X-rays varies with the water contents of the seeds at the moment of irradiation. Even in the air-dried seeds an impediment occurred according to the water content and the doses given.

(4) Seeds having a water content of 57% and up seem to have been severely affected by 20 H up.

(5) From the fact that seedlings from irradiated seeds, whether peeled or not, grow alike, it is presumed that the presence of the seed coat does not affect the germination. That is, a dose above 20H became an injurious stimulation for the plumule and radicle in steeped irradiated seeds with ca. 58% water.

(6) The sprouting of air-dried irradiated seeds is delayed more than that of steeped irradiated ones. The retardation of sprouting may be due to the fact, that the latter, whose water content is large, are more stimulated than the former having less water. If the sprouting is delayed, the growth will do so, and a retardation of the time of bloom will naturally take place.

Botanical Institute, College of Agriculture,
Imperial University, Tôkyô.
June, 1922.

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EXPLANATION OF PLATES.

PLATE XI.

Fig. 1. Seeds of "Sengoku-kurome" were steeped in water for 16 hours (when the water contents reached 57.19%) and exposed to rays on March 17, 1917. On the next day they were sown 24 hours after irradiation in Marquis Tokugawa's field at Azabu, Tōkyō. The figure shows the conditions at the end of the experiments on May 10.

(Of ten seeds of each lot these are the remainder of the seedlings, while the rest were found decayed or altogether missing.)

Fig. 2. Seven seeds, from the batch of Experiment I, were sown 17 hours after irradiation in the soil of large wooden frames and 7 *suo* pots. The picture represents their condition at the end of the experiments on May 22, 1917 (these are the remaining seedlings, from seven of each lot.)

Fig. 3 and 4. After 31 hours steeping, the seeds of "Sengoku-kurome" were irradiated, their water contents reaching 50%, on March 31, 1917. They were sown, on April 1, 17 hours after irradiation in the field of our institute. Photographed on May 1. They are shown standing in the field.

Fig. 5. Conditions of plants of each lot from Figs. 3 and 4 at the end experiment, June 16.

Fig. 6. Seedlings which were used for the culture in Knop's solution. Two seeds, from the batch of Experiment III, were sown in saw-dust on April 2. On April 9 they were put into Knop's solution and photographed on April 16. The seedlings of 50 H (due to injury) and 80 H up did not develop further than this stage.

Fig. 7. Condition of the above water-cultured plants 22 days after treatment, on May 1, A black point of a 30 H-plant which exists at the lower part of a shoot was caused by injury. Therefore, the growth is inferior to that of the others.

Fig. 8. Condition at the end of experiments, on June 16, of the plants of Fig. 6.

Fig. 9. Plants grown from the seeds of "Hyôgo" which were steeped for 24 hours before irradiation when the water content reached 57.32% irradiated on Oct. 28, '17 and sown the next day. State on June 22 at the end of experiments.

PLATE XII.

Fig. 10. Fruits from the above plants. These plants of Experiment V were seriously damaged by *Pipistrillus abramus*. The number shown on some plants and fruits of 20 H coincides in two figures; they are the number of individuals in the field.

Fig. 11. Plants grown from seeds of "Hyôgo" which were steeped 34 hours before irradiation (when the water content reached 63.37%) and irradiated on Oct. 28, '17. On the next day they were sown, 22 hours after irradiation, in the field of our institute (the field for Experiment III). State at the end of experiment, June 22, '18.

These plants of Experiment VI were also severely damaged by *Pipistrillus abramus*.

Fig. 12.   Fruits of above each lot.   In two figures, the coinciding number of 10 H-plants and fruit are the number of individuals in the field.

Fig. 13.   The state (at the time of crop) of plants grown from air-dried seeds of " Hyôgo," whose water content was 13.75%, were irradiated on Oct. 28, '17, and, on the next day sown, 22 hours after irradiation, in the field of our institute.   Photographed on June 22, '18.

Fig. 14.   Fruits of above each lot.   In two figures, same number in different lots, e. g., No. 8 is in 40 H- and 60 H-fruits and No. 4 is in 60 H- and 80 H-fruits, but these are simply the number of individuals in the field.   Fig. 14. represents the fruits of each lot in Fig. 13.

Fig. 15.   Shows the seeds of each lot.   The numerical number of each lot is that of individuals in the field and common to three figures (Figs. 13–15).

Fig. 16.   The whole crop of each lot of Experiment VII, and one pile is the crop from one plant.   It can be seen that the amount of crop decreases proportionally to the increase of doses given, and that of the 80 H is extraordinary small.

Fig. 17,   Seedlings grown from the seeds of " Hyôgo " which were steeped for 77 hours (when the water content reached 57.87%) and irradiated on April 19, 1919.   On that evening they were sown in sands a few hours after irradiation.   Photographed in the forenoon of April 27. The lower row represents those from peeled seeds.   (Experiment VIII).

The irradiated seeds are almost in the same stage of growth and no difference in growth is seen proportional to the doses given.

Fig. 18.   Seedlings grown from the air-dried seeds of " Hyôgo," water contents of 10.40%, irradiated on June 25, 1919 and sown in sand.   Photographed on June 30.

No sign of acceleration of germination can be seen (Experiment IX).

Plate VI.

6OH   40H   30H   20H   Normal

7.

NORMAL   20H   30H   40H   60H

8.

Control   20H

9.

Plate XI.

1.

2.

3.

4.

5.

6.

7.

8.

9.

Plate XII

16.

17.

18

Plate XII

20H

Control

10.

Control   40H   50H   60H   80H

13.

16.

Control   10H

11.

80H   60H   50H   40H   Control

14.

20H   40H   50H

17.

10H

Control

12.

40H   60H   80H

8   3   8   6

15.

Control   7H   10H   15H
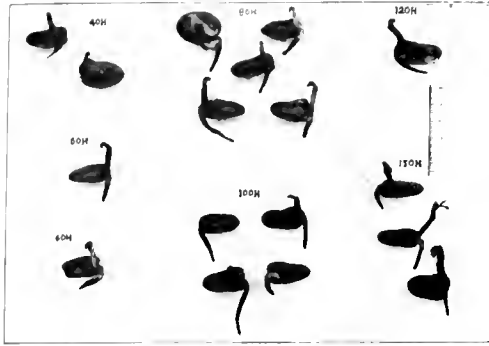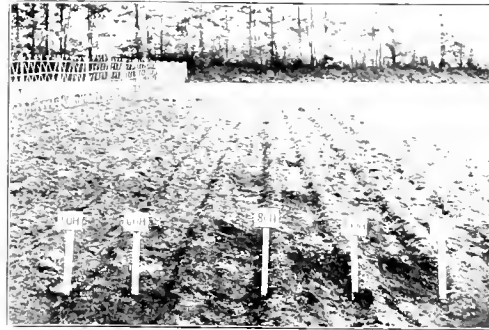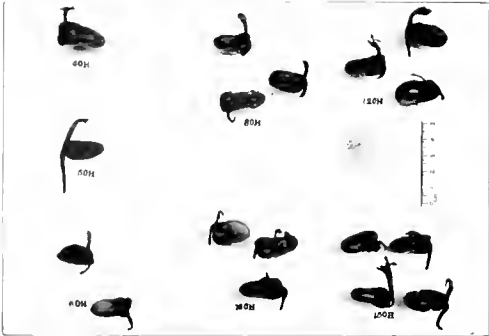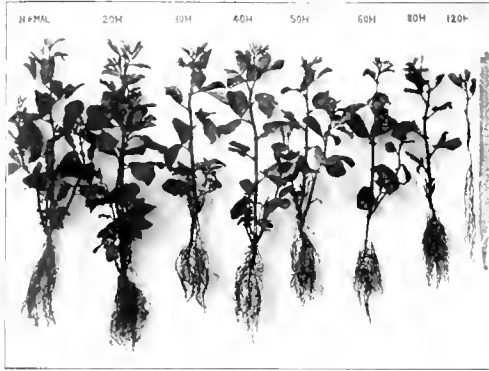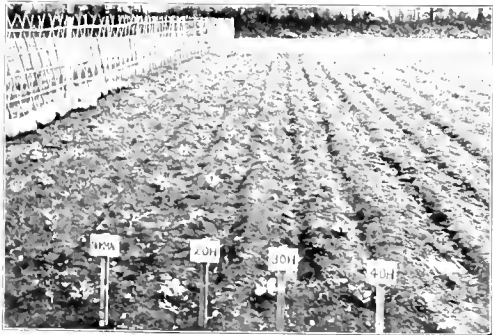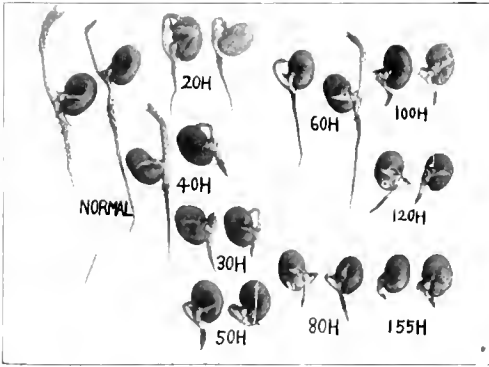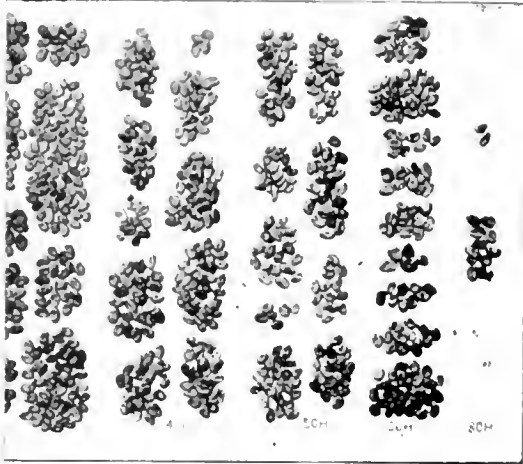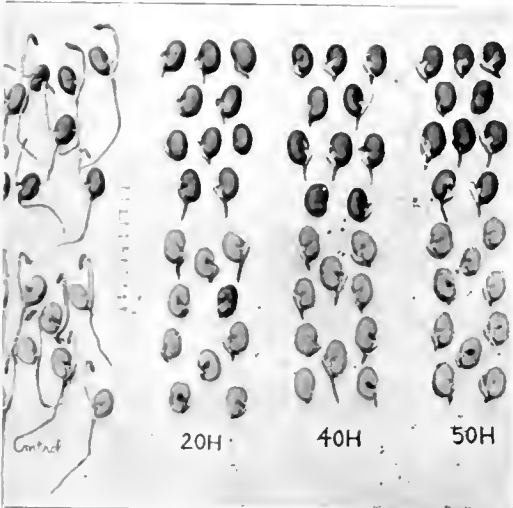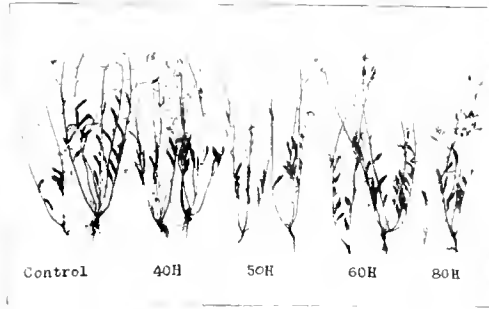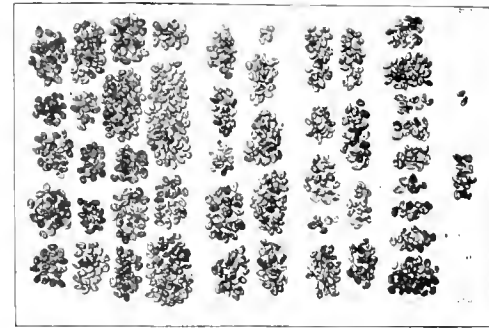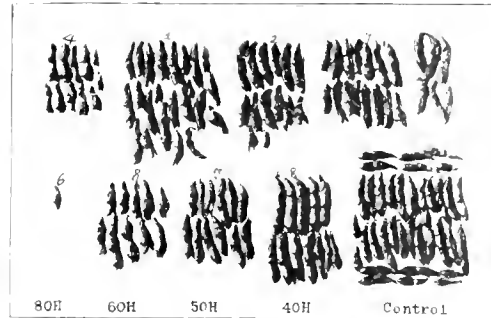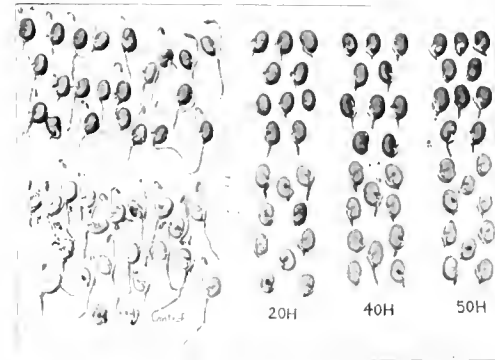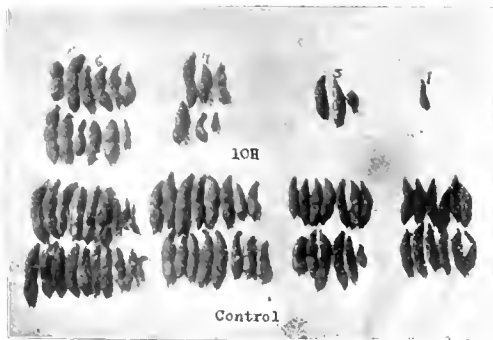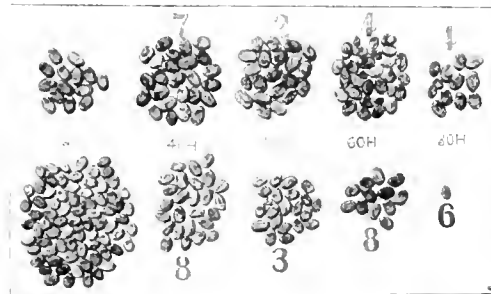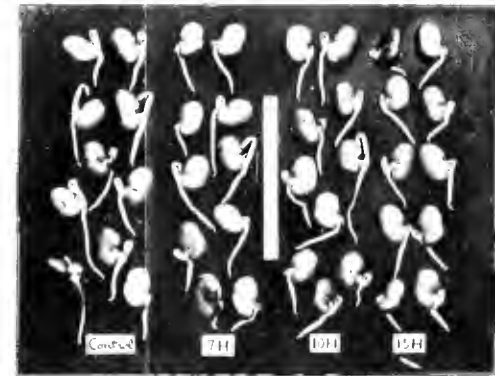
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CONTENTS.

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All communications relating to this Journal should be addressed to the
Director of the College of Agriculture.

Contributions to the Comparative Study of the So-called Scombroid Fishes.

By

Kamakichi Kishinouye.

College of Agriculture Tokyo Imperial University

With Plates XIII XXXIV and 26 Text-figures.

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Diagram showing a new scheme of classification of the scombroid fishes

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Euthynnus

Auxis

Katsuwonidæ

Neothunnus

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Thunnus

Thunnidæ

PLECOSTEI

Gymnosarda

Sarda   Cybium

Acanthocybium

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Cybiidæ

Rastrelliger

Scomber

Scombridæ

Other Acanthopterygian families of
the **TELEOSTEI**

Diagram showing a new scheme of classification, adopted in this monograph, of the genera and families of the so-called scombroid fishes found in Japanese waters, and their probable relations with each other.

Introduction.

Japanese naturalists of olden times, such as EKIKEN KAIBARA (38), JYUBEI KURODA (50), and SHYUSAKU TAKEI (73), arranged the scombroid fishes in four groups:—mackerels, scerfishes, tunnies, and bonitos. Though these authors did not mention the general characters of these groups, I do not hesitate to say that their observations were keen and accurate.

In the occident, LINNAEUS and his followers grouped the scombroid fishes in a single genus *Scomber* without order; but in 1829 CUVIER founded a new classification, and arranged the scombroid fishes (les Scombres) in eight genera: — *Scomber, Thynnus, Oreynus, Auxis, Sarda, Cybium, Thrystes, and Gempyles.* This system has been followed by succeeding authors, though more or less altered by them. Thus at present tunnies and bonitos are classified with scerfishes and mackerels together in one and the same family, Scombridae, and even many recent investigators who have the tendency of dividing old families into many new ones have not yet touched this family. REGAN (62) observed that the definition of the family Scombridæ is not satisfactory, and the natural affinities of different genera are little explained. Recently STARKS (69) tried to solve the mutual relationship of scombroid fishes from the study of the skeleton, and published valuable results.

The scombroid fishes are of great consequence in the economy of our country, ranking next in importance to the clupeoid fishes. Their annual catch amounts to ca. 150,000,000 kg. in weight, and 25,000,000 yen in value. These figures are based on statistical reports from the government, and I believe that they are much underestimated. Of course the amount of catch fluctuates yearly; but there is a tendency to gradual increase, as the fishing grounds are more and more extended. Though these fishes are caught nearly in every part of our empire, and the whole year round, they are more abundant in southern parts, and more on the Pacific coasts than on the Japan Sea coasts. Recently Japanese fishermen have begun to catch tunnies and bonitos in great abundance in the Hawaiian waters and in South California.

The scombroid fishes are mostly migratory, swim near the surface of the sea, and are very widely distributed. They form large schools, grow very rapidly, mostly attaining a gigantic size, and furnish a rich, palatable, nutricious food.

I began the investigation of the scombroid fishes in 1911, and since then I have devoted my time chiefly to this study. As the result of the investigation, tunnies and bonitos were found to be the most specialized forms of the bony fishes with many distinctive characters, hitherto unknown to science. The results have from time to time been reported in Japanese in the "Suisan Gakkwai Hô" (Proceedings of the Scientific Fishery Association).

The materials for the present study were chiefly collected at our laboratory from the fish-markets of Tokyo, and a part from various localities by the author himself, and through the courtesies of institutions and private persons. The author wishes to acknowledge with thanks the kind assistance of Messrs. SEIZŌ ADACHI, YEIJI AKIYAMA, TAKEO AOKI, HIKOTARŌ ASANO, KOICHI KAMEI, NIHEI MATSUNO, the late KŌTARŌ MAYEDA, YŌZŌ NAKAJIMA, SEISHI OKADA, NAOTARŌ OTA, YASUJI OHTA, KATSUYA TAGO, KIYOTOMO TASHIRO, SEIJIRŌ TOMINAGA, YŌJIRŌ WAKIYA, KICHITARŌ YAMADA &c., besides many friends in our College,

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Comparative Anatomy.

EXTERNAL CHARACTERS.

EXTERNAL FORM OF THE BODY.

In general the form of the body is nicely fusiform, so as to give the least resistance in locomotion, but in the case of *Cybium chinense* the anterior part of the dorsal outline is concave (fig. 34). The ventral outline of the body is a little more curved than the dorsal, to balance the heavy muscular part with

1. One of the pioneers who established the tuna fish trade in South California.

the lighter, visceral part. The posterior end of the body is more slender than the anterior, the broadest part of the body being generally in advance of the middle, between the snout and the caudal peduncle. In mackerels the broadest portion is found in the vertical, passing the middle of the first dorsal, that is a little before the middle of the body. In seerfishes the broadest part lies at the posterior part of the first dorsal or near the anus. In tunnies the broadest part of the body is at the middle of the first dorsal, while in bonitos the broadest part nearly coincides with the middle of the body. The body is generally rounded or elliptical in cross-section. In *Rastrelliger* and most species of the genus *Cybium* the body is more or less compressed; but in the Plecostei the body is always plump.

Generally the line connecting the apex of the snout and the middle of the side of the tail passes through the centre of the eye, and nearly coincides with the upper margin of the pectoral fin. In the Scombridæ the nape is narrow, and the body is more or less compressed laterally; in the Cybiidæ the nape is broad, and the body is generally compressed and elongated; while in the Plecostei the body is short and plump. In the Thunnidæ the nape is broad, but in the Katsuwonidæ it is remarkably narrow. The caudal portion is shorter than the abdominal portion in the Scombridæ; longer in the Cybiidæ, except in the genera *Acanthocybium*, *Sarda*, and *Gymnosarda*; nearly equal in the Thunnidæ; and shorter in the Katsuwonidæ. In the Scombridæ the caudal peduncle is thick, nearly rounded in cross-section and wants the lateral keel, while in the Cybiidæ it is rather thick, more or less horizontally depressed, and is provided with a large lateral keel, which is rather thin and broad at the hind end. In the Plecostei the caudal peduncle is very narrow, depressed, and is provided with a very thick keel, especially in the Katsuwonidæ. In the Cybiidæ these keels are generally covered were elongated scales, but they are quite naked in the Plecostei.

The form of the body differs of course in different ages of fish. Generally the head is longer in small, immature specimens, but the proportion of its length to the height of the body is often constant. Therefore immature specimens of seerfishes and their allied forms, such as *Cybium niphonium*, *C. commerson*, and *Sarda orientalis* are broader than the mature forms; but in the Plecostei the immature forms have a more slender body than the adult. The

form of the body differs sometimes in different seasons. Generally the form of the body is fat and fine before the spawning season; but it becomes lean and ugly after spawning, and remains in such a condition during some three or four months. The lean form of *Cybium niphonium* in summer is especially remarkable. This difference of fatness in seasons is little discernible in the case of the Plecostei. In the striped bonito, however, the flesh becomes remarkably watery after spawning, much paler in colour, and at the same time losing both taste and tenacity.

Size of the Body.

Mackerels are generally small, never reaching one metre in the total length. Scerfishes generally grow more than a metre in length, and certain species attain a very large size, for example *Cybium chinense* grows to a length of more than two metres, and to a weight of more than one hundred kg. *Gymnosarda nuda*, *Cybium commerson* and *Acanthocybium solandri* grow very large too. Much larger sizes are rather common in tunnies. *Thunnus orientalis* grows to more than 260 kg in weight, and ca 3 m in length, and even tunnies of 375 kg are recorded. Thus our common tunny is smaller than the Atlantic congener, the latter is said to grow to ca 451 kg in weight. *Neothunnus rarus* is the smallest tunny known, reaching maturity when it is ca 60 cm in length, and 8 kg in weight, being nearly equal to the average size of the striped bonito. In bonitos the size becomes small again, rarely exceeding a metre in length, and 15 kg in weight, the smallest fish of the kind is found in the genus *Auxis*. Fishes of the genus *Auxis* are ca 30 cm long and 600 g in weight.

Colour and Markings.

The back is blackish at the anterior part, changing gradually to bluish or greenish colour, with metallic lustre, and the belly is silvery or greyish, with irridescent reflections. Generally speaking the ground colour of the back is greenish in the Scombridae, steel-blue in the Cybiidae, and bluish in the Plecostei. When we observe the living fish, the colour greatly differs from that of the dead, even recently killed. I have observed a remarkable difference in the genus *Auxis*, which is dark bluish green when living, but bluish when

dead. The colour of the living fishes is, however, very difficult to observe, as they live rather in off-shore waters, swim very swiftly, and die soon after they are caught. A yellowish colour is found in mackerels and most tunnies, but is not found in fishes of the Cybiidae, nor in bonitos. Moreover, this colour is not stable in specimens preserved in alcohol or formalin.

Markings are mostly found on the back, and they are generally blackish. They are either irregular, waving streaks, dots, or longitudinal bands, and those found in the back are darker than the ground colour. Markings are sometimes found in the belly too, but they are sooty, fainter than those on the back, or are silvery in the sooty ground. The number of the markings corresponds generally with that of myotomes. Markings on both sides of the body are not strictly symmetrical. Colour and markings fade away in long preserved specimens. On the contrary markings invisible in fresh state may become visible after some days preservation in alcohol or formalin. Colour and markings of the immature forms differ greatly from those of the adult. Generally, immature fishes have simpler and less numerous markings than the adult; but in the striped bonito immature fishes have more numerous stripes than the adult.

Colour and markings become bright, when the fish is excited, and dull, or disappear when frightened.

In our common mackerels pigments are found below the skin, and above the adipose layer, and in the skin which may easily be peeled off, scanty, insignificant pigment-spots only are found. This explains the reason why stale mackerel often retain brilliant colours. In *Rastrelliger chrysozonus* we find a row of dark spots on each side of the base of the dorsal fin, besides two dark longitudinal bands in the back. Two bands below these dark bands and running behind the pectoral are yellowish. The yellowish colour gradually fades in preserved specimens.

Seerfishes have generally two or more rows of dark roundish spots near the lateral median line of the body. In *Cybium niphonium* (fig. 32) we sometimes find the whole body except the back densely covered with spots. In the same species the ventral median line, and a longitudinal line running backward from the base of each pectoral are sometimes coloured black. *Cybium commerson* (fig. 39) and *Acanthocybium solandri* (fig. 31) have many transverse

bands, while the fish belonging to the genus *Sarda* have many longitudinal bands on the back (fig. 33). In a small immature specimen of *Sarda orientalis*, obtained on the east coast of Aomori-ken, I found 13 transverse bands, and in these bands, five to seven, oblique longitudinal bands, were found. Fishes belonging to the genus *Gymnosarda* have no markings at all (fig. 37). In the Cybiidæ dots and bands are generally few in number in immature forms, and the markings increase in number by intercalation as the fish grows larger. *Cybium niphonium* under 10 cm in length, and *Cybium koreanum* under ca 20 cm lack markings entirely.

In adult tunnies we find no markings, except many silvery lines and dots in the belly of certain species (fig. 45, 48). These silvery dots and lines are not found in the other scombroid fishes. Adult bonitos have dark bands generally transverse in the back; but they are not conspicuous in the genus *Katsuwonus* (fig. 53), as the bands are very broad and quite near each other. Longitudinal bands on the belly of *Katsuwonus* and dark spots in the thoracic part of *Euthynnus* (fig. 54) are characteristic to the respective genus. Generally small immature forms of plecostean fishes are transversely banded and they extend from the dorsal median line to the ventral median line. These bands are broad and they approach each other very closely, in the Thunnidæ; but in the Katsuwonidæ they are rather narrow, being more narrow than the interval between them, and are short, not reaching the ventral median line. Small immature forms of *Thunnus orientalis* (fig. 43) and *Neothunnus macropterus* have many dark transverse bands, which gradually disappear from the dorsal side, when the fish is about half a year old; but the ventral part of these bands remains all through life (fig. 45). As the fish grows larger, these bands in the belly are subdivided by a series of dots. These boundary lines and series of dots gradually incline obliquely backwards, towards the ventral median line (fig. 45). In *Parathunnus mebachi* of ca. 90 cm in length I found ventral markings, but in larger specimens they disappear entirely. In *Thunnus germo* and *Neothunnus rarus* (fig. 48) irregular longitudinal bands of greyish colour are found in the belly, and they anastomose with each other, leaving silvery meshes. In the former species the marking disappears in larger specimens, but in the latter, it remains lifelong. Pigments and silvery ingredients of bonitos are found at the surface of the skin. Therefore when

we peel off the skin, the colouring is mostly lost, and only a thin pale layer of pigment is found above the adipose layer of the body. Sometimes the belly of bonitos is sooty brown. Fishermen believe that such fishes remained on the muddy bottom a long time. In a small specimen of *Katsuwonus pelamis*, ca. 20 cm long, I found 5 faint transverse bands near the lateral medium line, besides the longitudinal bands. These transverse bands are called by fishermen bands of the *sword*-type, and when these bands appear on the side of the fish, they are greatly excited to bite so that we can anticipate a great catch. In immature bonitos ca. 30 cm long, longitudinal bands are more numerous than in the adult, the auxiliary bands being found near the lateral median line. In immature specimens of *Euthynnus yaito*, ca. 13 cm long, we find about eight transverse bands, crossing down the lateral line. These bands are darker and bend a little backward at the dorsal part above the lateral line. In a specimen ca. 19 cm long there are about thirteen transverse bands. The course of the dorsal part of the bands above the lateral line now nearly coincides with the boundary line between myotomes. Specimens of such size have one to three dark spots at the pectoral region.

The spinous dorsal, caudal, and the axial side of the pectorals are generally blackish. Ventrals and the anal are pale coloured or nearly colourless. In the Cybiidæ the spinous dorsal is generally black, but in immature forms of some seerfishes it is colourless at the posterior portion. In *Gymnosarda* (fig. 37) the tip of the second dorsal and the anal is colourless. In the *Plecostei* the first dorsal is washed with black at the margin. It is remarkable that fins are more or less yellowish in tunnies; but that colour never appears in the fins of seerfishes and bonitos. The yellow colour is especially conspicuous in *Parathunnus mebachi* and *Neothunnus macropterus*; but not conspicuous in *Thunnus germo* and *Neothunnus rarus*.

HEAD.

Generally speaking the head is large, one fifth of the total length of the body in the Scombridæ, one sixth in the Cybiidæ, and one fourth in the Plecostei. The length of the head is generally more or less longer than the height of the body, even in the case of tunnies and bonitos. Therefore it is very remarkable that the head of *Cybium koreanum* is $1\frac{1}{2}$ times the height

of the body (fig. 35). The head is somewhat triangularly pyramidal, as its upper surface is more or less flat and the lateral sides oblique, meeting at the ventral median line. This characteristic form is very well developed in the Plecostei, while it is rather a little modified in the Cybiidæ, as the head is more compressed laterally than in other families, and its top is more or less vaulted.

In the Scombridæ the snout is moderately long, ca. 1/3 the length of head, and the posterior nostrils are slit-like. In the Cybiidæ the snout is much elongated, being nearly equal in length with the part behind the eye. The anterior and posterior nostrils are nearer to each other, than in the Scombridæ and Plecostei, and the posterior nostrils are more or less elliptical and a little larger than the anterior. In the Plecostei the snout is ca. 1/3 the length of the head, but it seems rather short, as the head is broad. In the genus *Auxis* the snout is very short, being only ca. 1/4 the length of the head. The Japanese name for the fishes of that genus is "medika," which means that the eye is near the snout. The anterior nostrils are quite small, and the posterior nostrils are mere slits.

The mouth is terminal, not protractile. In the Scombridæ it is rather wide, the hind end of the upper jaw reaching or passing beyond the vertical from the middle of the eye; and the margin of the upper jaw is mostly formed by the preorbital. The supplementary bone to the maxillary is very narrow and small in this family. In the Cybiidæ the mouth is very wide, the posterior end of the upper jaw generally reaching beyond the posterior margin of the eye. But in *Acanthocybium*, *Grammatorcynus*, and *Gymnosarda* the maxillary scarcely reach the vertical from the center of the eye. In *Acanthocybium* the preorbital forms the posterior part of the upper jaw. The supplementary bone to the maxillary has its posterior end rounded. In the Plecostei the mouth is comparatively small, the posterior end of the upper jaw not reaching the vertical from the middle of the eye. The supplementary bone to the maxillary has a broad straight side at the posterior end. An obliquely downward grove in the skin from the gape of the mouth is deep and conspicuous.

In the so-called scombroid fishes the teeth in the jaws are arranged in one row only. They are a little more numerous in the upper than in the

lower jaw. They are formed in alveoles and are replaced by new ones coming out between the old. In the Scombridæ the teeth are very minute. Indeed the Japanese name "saba" for the mackerel means minute teeth in our old language. The vomerine teeth when present are arranged in two lateral patches, and the palatine teeth when present are in one row only. In the Cybiidæ the teeth are well developed, long, curved, laterally compressed, and generally trenchant at the edges. Thus seerfishes are voracious, and often hurt fishermen and damage fishing apparatus too. Teeth on the vomer and palatines are villiform. In the Plecostei the teeth in jaws are small, conical and curved. In the Thunnidæ villiform teeth are found on the vomer, palatines, and pterygoids. Mesopterygoid teeth are remarkable, as they are not found in the other fishes. In the Katsuwonidæ the teeth are found in both jaws only; but in the genus *Euthynnus* palatines and sometimes the vomer too are toothed. In these cases the teeth are arranged in one row only, and they are rather large.

The eyes are comparatively small in the Cybiidæ, being contained more than 7–10 times in the length of the head, and more than 30–40 times in the total length of the body; but they are large in *Gymnosarda*. In the Scombridæ and Plecostei the eyes are large, being contained less than 6–10 times in the head, and 18–27 times in the body. In the Scombridæ the adipose eyelids are remarkably well developed. In the Cybiidæ and Plecostei the eyelids scarcely cover the eye-ball. *Thunnus germo* and *Parathunnus mebachi* have large eyes, these tunnies descend to the deeper strata of waters. The eye-capsules are well developed and more or less calcified in the Plecostei.

LATERAL LINE.

The lateral line more or less undulates. In the Scombridæ, however, the undulation is insignificant, being nearly straight from the nape to the caudal peduncle, running more or less parallel to the dorsal median line of the body, and the perforated scales in the line are only a little modified from other scales. In the Cybiidæ the lateral line runs generally parallel to the dorsal median line of the body for some distance from the nape, and at the caudal part the lateral line nearly coincides with the lateral median line of the body. These two portions of the lateral line are connected by an oblique portion.

The position of this oblique portion is either under the first dorsal or under the second. In fishes of this family the lateral line often sends out many branches on both sides (figs. 31, 32, 35), and these branches are vertical in *Acanthocybium*, but oblique in *Cybium*. The perforated scales are larger, thicker, and greatly modified in their form, and they may also distinctly be seen on the lateral keel of the caudal peduncle, at the trenchant edge.

The lateral line of *Cybium koreanum* (fig. 35), *C. guttatum* (fig. 61), *Sarda orientalis* (fig. 33), and *Gymnosarda nuda* (fig. 37), differ more or less from the typical form. In *Grammatorcynus* two lateral lines are found on each side of the body (fig. 62). The upper lateral line seems to correspond to the normal lateral line, running parallel to the dorsal median line of the body. The lower lateral line joins the upper with a right angle behind the pectoral, and running down backward approaches the ventral median line, a little behind the ventrals. Thence the line runs parallel to the ventral median line, and meets the upper lateral line, a little anterior to the lateral keel.

In the Plecostei perforated scales are very little modified, and the undulation of the lateral line is not much pronounced; but it has a more or less characteristic feature in different families. It is worthy of note that the lateral line of the Thunnidæ always takes a peculiar course, above the pectoral (figs. 43, 45–48). In this region the course of the lateral line is rather difficult to trace, as the pores are indistinct, few in number, and much separated from each other. The lateral line of *Thunnus orientalis* is typical. The lateral line of the *Katsuwonidæ* has only a slight rise above the pectoral, and has small undulations at the caudal portion. KLUNZINGER (49) wrote in the diagnosis of *Thunnus thunnina* as follows:—

" Die Seitenlinie bildet zuweilen eine Knickung nach oben über der Mitte der Brustflosse ; dann senkt sie sich, etwas unregelmässig wellig laufend, bis zur Mittellinie."

This description is well adapted to the lateral line of tunnies, but not proper for that of bonitos. Indeed the author confounded immature tunnies with bonitos, identifying *Orcynus schlegeli* of STEINDACHNER (immature form of our common tunny) with *Thynnus thunnina*.

Skin and Scales.

The skin is thick and well developed, and its deeper layer, the dermis, is composed of several layers of oblique connective tissue, running in two different directions, more or less perpendicular to each other, and alternating in succession. The skin is more or less elastic, and extensile longitudinally, but almost nonextensile transversely. In the Scombridæ we count only two layers of connective tissue in the skin, in the Cybiidæ four layers, and in the Plecostei about six layers.

Scales of the so-called scombroid fishes are generally described as cycloid, but most of them are imperfectly ctenoid, as they are toothed at the posterior margin, and have no striation or only faint striation at the surface. In the Scombridæ scales are nearly cycloid, almost equal in size and form, everywhere in the body, except those scales on the second dorsal, anal, and the middle part of the caudal fin. Scales in these parts are small and slender. In the Cybiidæ scales are small, thin, and are often concealed under the skin or disappear from the most part of the body. The differentiation of scales is more marked than in the Scombridæ; those on the lateral line and those near the dorsal and ventral median lines are longitudinally elongated and densely crowded. Scales at the pectoral region are larger and more or less differentiated to form the corselet. In the Plecostei the corselet is very well developed. Scales in it are very thick, and it is covered by a tough membrane, so that the pectoral region is doubly strengthened, probably to protect the thick portion of the cutaneous blood-vessels, peculiar and very important to the Plecostei. The scales on each side of the base of the first dorsal are pretty large, rhombic, and are arranged in several longitudinal rows. Small elongated scales are found on the external side of the pectoral, and sometimes at the base of the ventrals and on the caudal. In the Plecostei scales round the pectorals are small and elongated. In the Katsuwonidæ scales are not developed outside the corselet; but in an old striped bonito I found minute scales scattered here and there outside the corselet. These scales are roundish and have a few concentric striæ. In the Scombridæ and Cybiidæ small scales are found on the opercular bones; but in the Plecostei these bones are entirely naked. Scales on the cheeks are much modified,

elongated and arranged as if radiating from the eye. In the Scombridæ these scales are especially large and unequal in size.

The scales of the Scombridæ are longitudinally striated near the posterior margin, besides the striation parallel to the posterior margin. Scales of the Cybiidæ are mostly concentrically striated, and those of the Plecostei are mostly smooth at the surface and have a dentritic lumen inside. Very narrow scales, arranged longitudinally and very thickly together, are found on the second dorsal, caudal and sometimes on the external surface of the pectoral, contributing to strengthening these fins and at the same time to make their surface more smooth.

Fins.

The fins are generally well developed, stout, rigid, and are adapted for swift locomotion. Some one says that the fins of the male fish are larger than those of the female; but I have no fact material to corroborate it. Like the development of other organs, fins are also best developed in the Plecostei. In the Scombridæ spines and rays in fins are feeble, slender, and fin-rays are transversely articulated as in most teleosteans. In adult forms of the Cybiidæ and the Plecostei, fin-rays are longitudinally divided at the distal end, but not articulated transversely, except in the genus *Grammatorcynus* and in the ventrals. The ventral fins therefore seem to play a not very important part in swimming in these fishes. The spines consist of single consolidated rods; but the rays are composed of two lateral halves.

The first dorsal fin may be entirely folded into a groove. The other median fins may more or less be divaricated in the Teleostei; but in the Plecostei they are nearly solid, and their form and dimension is little altered.

The pectorals are rather high in position, pretty well developed, and when depressed each of them rests in a shallow depression, the dorsal margin of which generally coincides with the line, connecting the centre of the eye with the lateral median line of the caudal peduncle.

When the pectorals are in motion, they are spread out horizontally and their fore margin lies in a straight line, perpendicular to the axis of the body. Thus when we look at *Thunnus germo*, swimming in the sea, spreading its extraordinary long pectorals, we conceive a dragon-fly in flight, hence our

fishermen call the albacore " tombo-shibi ", meaning the dragon-fly tunny. The number of fin-rays in the pectoral is 18 in the genus *Scomber*, 19 – 24 in the genus *Cybium*, 25 in *Gymnosarda*, 30 – 36 in the Thunnidæ, ca 30 in *Katsuwonus* and *Euthynnus*, and ca 25 in *Auxis*. Thus in general the number of fin-rays in the pectoral increases as the structure of the body becomes more complicate, and again decreases as the structure degenerates. The expanse of the pectoral is nearly unchanged, though the number of rays is increased. There is no doubt that the greater number of fin-rays increases the rigidity of the fin itself. In the Scombridæ the pectorals are small, triangular, and are situated a little higher than in the Cybiidæ and Plecostei. In the Cybiidæ the pectorals are also small, often broad at the origin, and more or less crenulated at the ventral margin, as in *Cybium niphonium*, *C. guttatum* and *Gymnosarda nuda*. In *Cybium chinense*, however, the pectorals are large, and rounded at the posterior margin (fig. 34). The form is quite extra-ordinary. In the Thunnidæ the pectorals are generally long, reaching the origin of the second dorsal, and even pass beyond it. These fins gradually tapering behind, are sabre-shaped. In the Katsuwonidæ the pectorals are small and triangular. They are pointed at the posterior dorsal end. In *Sarda* and Plecostei a special elastic protuberance or rather a ridge is developed at the inner or dorsal side of the root of pectorals to fit tightly to a corresponding groove on each side of the body.

The ventrals are thoracic, moderate in size, always composed of one spine and five fin-rays, and as in many other fishes fit to depressions of the body when folded. These fins seem to be of secondary importance, as their fin-rays remain transversely articulated, and they are reduced in size in the Cybiidæ, being smaller than the anal, except in the genus *Gymnosarda*.

The dorsal is divided into two, first and second, and the posterior portion of the latter is further divided into many finlets. In the Scombridæ the number of finlets is generally 5, in the Cybiidæ 6 – 9, and in the Plecostei 8 or 9. The first dorsal is never continuous with the second, and is formed of several spines which when depressed are wholly received in a groove. The tip of the spines of the first dorsal is flexible, and each spine has a hole at the proximal end. In the Scombridæ and also in the genus *Auxis* of the Katsuwonidæ, the two dorsals are separated by an interspace from the

suppression of some posterior spines, and in these cases the first dorsal is
short but rather high, higher than the second dorsal. The first dorsal of the
Scombridæ originates from the myotome of the second vertebra, while that of
the other so-called scombroid fishes originates from the myotome of the first
vertebra. Therefore the origin of the first dorsal in the Scombridæ is well
behind the origin of the pectoral fin, while in the other groups the former
and the latter lie nearly in the same vertical. In the Scombridæ the spines
of the first dorsal are very feeble, and the first spine is shorter than the
second, which is generally the longest (figs. 28, 29). In the Cybiidæ the first
dorsal is generally low, long, mostly black, and its outline is more or less
convex, gradually descending backwards (figs. 31–37, 61, 62). The first spine
is not the longest as in the Scombridæ. The first dorsal of *Acanthocybium
solandri* differs from that of allied fishes in being broad and of nearly the
same breadth throughout (fig. 31). In *Cybium* the height of the first dorsal
is 1,4–1,3 the height of the body. In the Plecostei the first dorsal is
generally high and the outline of its dorsal posterior side is concave, and its
first spine is always longest and thickest, the following spines, though
decreasing rather rapidly in length are also strong (figs. 43–48). In the
genus *Katsuwonus* the height of the first dorsal is best developed. The
longest spine is about 3,5 the height of the body. In other bonitos and
most tunnies the height of the first dorsal is contained about twice in the
height of the body.

The second dorsal and anal are nearly equal in form and size. The
former precedes the latter one myotome in *Scomber* and *Cybium*, and about
three myotomes in the Thunnidæ. Fin-rays of these fins grasp the distal
segment of the interspinous bone between the proximal ends of their lateral
halves. In the Scombridæ these two median fins are respectively smaller
than the spinous dorsal, and fin-rays of these fins are feeble and transversely
articulated. In *Scomber* moreover an isolated spine is found before the anal
as in the Carangidæ. In the Cybiidæ these two fins are pretty well developed,
generally higher than the first dorsal, and their fin-rays are thick and
nonarticulated. As some anterior fin-rays of these fins are well developed,
their form becomes falcate. They are pretty large, well developed in *Cybium
koreanum* (fig. 35) and *C. guttatum* (fig. 61); but are poorly developed and

small in *Acanthocybium* (fig. 31), *Grammatorcynus* (fig. 62), and *Sarda* (fig. 32). In the Thunnidæ these fins are falcate, conspicuously developed, and interspinous bones supporting fin-rays of these fins are remarkably broad. In some forms of *Neothunnus macropterus* these fins are unusually developed, brightly coloured, and their tips nearly touch the terminal points of the caudal. In tunnies as well as in *Cybium* these fins gradually elongate with the age of the fish. In immature tunnies and also in bonitos the second dorsal and anal are smaller than the first dosral (figs. 43, 53–56). These fins are very small in the Katsuwonidæ, especially in the degenerated genera, *Euthynnus* and *Auxis*.

The caudal fin is strong and lunate. Its two lobes are nearly equal in size and form, but the upper lobe is often slightly larger. In the Scombridæ the fin-rays are soft, thin, and transversely articulated. In the Cybiidæ the size of the caudal is comparatively large, and its fin-rays are thick, and non-articulated. The longest fin-ray in one lobe of the fin makes an angle of ca 60° with the longest in the other lobe. The fin-rays next on each side of the median fin-ray project posteriorly at the middle (figs. 31, 36). In the Thunnidæ the fin-rays of the caudal are so thick and robust, that prehistoric fishermen apparently used it for spear-heads. A specimen of such an implement 21 cm. long, carved from one of these fin-rays of our common tunny, was discovered by Mr. GENSHICHI YENDO in a shell-mound in Miyatojima near Sendai, Miyagi-ken. The angle made by the longest fin-rays in the two lobes of the caudal is more than 90° in the Thunnidæ and Katsuwonidæ. Fin-rays of the caudal of the striped bonito are sometimes used as tooth-picks after being cleaned and bleached. Among the so-called scombroid fishes in our waters the caudal fin is largest in *Cybium chinense*, the length of its upper lobe being longer than the height of the body, and ca. 1,4 the length of the body (fig. 34). In *Cybium guttatum* (fig. 61) the caudal fin is also very large.

SKELETON.

The Scombridæ, Cybiidæ, and Plecostei differ a great deal from each other in the skeleton, the fundamental structure of the body. There seems to be very little relation between the skeleton of the Scombridæ and that of the Cybiidæ; but the gradual transformation of the skeleton of the Cybiidæ to

that of the Plecostei is obvious. The skeleton of the Scombridæ is unique
in many respects, but it is more or less related to that of the Serranidæ, and
it has a remote relation to the Carangidæ. The characters of the skeleton
of different scombroid fishes may well be understood by comparing the middle
transverse sections of vertebræ, shown in Pl. XVI.

In the Scombridæ the skeleton is weak and brittle. The cranial bones
are thin, and not firmly connected together at the anterior part. The
vertebræ are notably small, and only a little differentiated in form in different
regions of the body (figs. 7, 30). They are rather loosely connected
and devoid of deep grooves. The neural and hæmal spines, interspinous
bones, and suspensorium of the mandible are narrow and slender. In the
Cybiidæ the skeleton is also brittle. The hæmal spine is scarcely developed
in the precaudal region (figs. 38–42). The neural spine of some anterior
precaudal vertebræ is broad. Except these broad neural spines, the remaining
neural and hæmal spines, and interspinous bones are weak and slender. The
skeleton of *Sarda* (figs. 11, 42) and *Gymnosarda* (figs. 12. 38) approaches
the skeleton of the Plecostei in the development of the lateral keel, in the
vertebræ of the caudal peduncle, and the inseparable connection of these
vertebræ with each other. Grooves and ridges in vertebræ become conspicuous,
and the substance of the vertebræ becomes hard and compact, as the fish is
more highly specialized.

In the Plecostei the skeleton is hard, compact, and the cranial bones are
very firmly connected. The vertebræ are comparatively large, have many deep
grooves, and their differentiation in different regions is remarkable (figs. 13–15,
49–52, 57–60, 64). The neural and hæmal spines of the vertebral column
are thick and the interspinous bones are very broad. The development of long
hæmal spines in the precaudal region is remarkable. The so-called inferior
foramen is very broad, especially in the Katsuwonidæ, forming a basket-work
of the hæmal process. In this family the epihæmal spine or bony pedicle of
STARKS is particularly developed between the centrum of many vertebræ and
their hæmal arch.

SKULL.

In the scombroid fishes the skull is generally triangularly pyramidal, and

on the dorsal, posterior part we find five longitudinal ridges or crests. The median ridge is continuous to the occipital crest, separating the right and left lateral muscles, and affording the surface of insertion to the protractor dorsalis at the posterior part. The inner ridge or temporal crest of STARKS and cretes intermediares of CUVIER are found at the mid-dorsal bend of the epaxial part of the lateral muscle, while the outer ridges or pterotic crests separate the lateral muscle from the facial muscles.

In the Scombridæ the skull (fig. 30, a, b) is comparatively high, being nearly as high as broad, and is gradually pointed towards the anterior end. The lateral ridges on the dorsal sides of the skull converge forward, and disappear near the posterior margin of the frontals. Moreover there is a pair of short, accessory crests on the external side of the temporal crests. The pterotic processes are stout, sharply pointed and nonflexible. The temporal and pterotic crests are separated by a deep furrow and are connected at the posterior end with a nearly vertical ridge. Nearly the anterior half of the skull is directly under the skin, and is not covered by the lateral muscle.
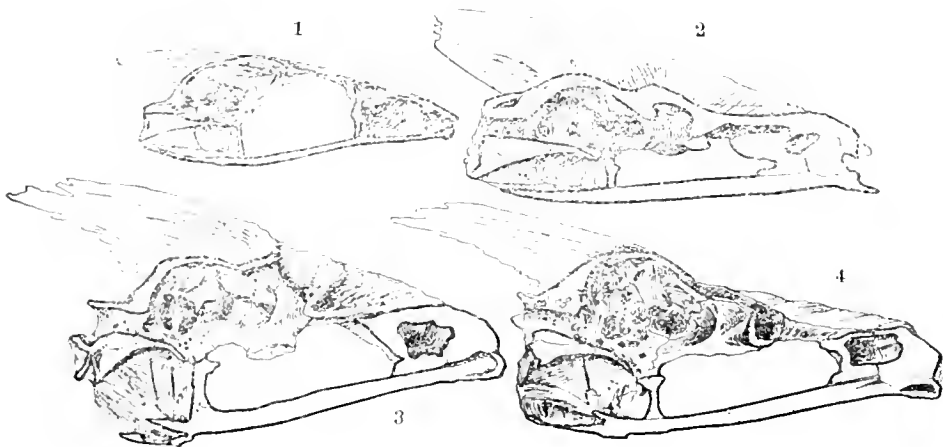
Fig. A. Median sagittal section of the skull. 1, *Scomber japonicus*; 2, *Cybium niphonium*; 3, *Thunnus orientalis*; 4, *Katsuwonus pelamis*. The first vertebra is anchylosed to the skull of *Thunnus*.

In the Cybiidæ the skull is elongated, low, and flat, especially in the ventral, temporal region. Generally the length of the skull is contained more than $1\frac{1}{2}$ times in its breadth. The dorsal crests are well developed, mostly running more than half the length of the frontals, and nearly parallel to each other. In the Plecostei the skull is short, only a little longer than broad, much broader than high, and we find high ridges and deep depressions on its ventral side or the auditory region of MASTERMAN. The development of these ridges and grooves differ greatly in different species. There are three foramina on the dorsal side of the skull, except in the genus *Auxis*. The inner dorsal or temporal crests diverging forward, while the outer ridges are converging; but in the Katsuwonidæ the inner ridges are nearly parallel to each other. The pterotic processes are long, flat, and flexible, especially in the Katsuwonidæ. In the Cybiidæ and Plecostei the posterior ends of the temporal and pterotic crests are connected with a straight ridge on each side of the skull, and the space between these two crests is nearly flat. In the Cybiidæ and Plecostei the dorsal surface of the skull is almost entirely covered with the lateral muscle, except in the cases of *Grammatorcynus*, *Acanthocybium*, and *Gymnosarda*. In the Plecostei there is a special chamber, posterior to the myodome, and below the basioccipital. The sides of the chamber are formed by the parasphenoid. So I shall name this chamber the parasphenoidal chamber. On the ventral side of the cranium, there are very deep depressions in the otic region. These depressions are quite peculiar to the Plecostei.

The ethmoid is a median bone, bounded by the frontals above, by the prefrontals at the lateral and posterior sides, and by the vomer and parasphenoid below. It has paired horn-like processes with a condylar surface for the maxillary at their ventral surface. In the Scombridæ, however, the condylar surface for the maxillary is found it the lateral ventral margin. The dorsal exposed surface of the ethmoid is crescent-shaped or Y-shaped in the Cybiidæ; but it is more or less trapezoidal in the Plecostei. The concavity at the front edge of the exposed dorsal surface of the ethmoid is to receive the premaxillary processes.

The prefrontals are paired bones, forming the anterior wall of the orbit, and lie between the vomer, parasphenoid, ethmoid, and the anterior part of the frontals. Generally they are massive, but in *Scomber* and *Gymnosarda*

they are thin bones, folded in different directions. The prefrontals are loosely joined with each other, as well as with other bones, except the vomer. They are longer than broad, and have only one articulating surface for the palatine in the Scombridæ, and also in the Cybiidæ, except *Sarda* and *Gymnosarda*. In these genera and also in the Plecostei the bones are nearly as long as broad, and have no articulating surfaces for the palatine. The olfactory nerve passes through the middle of the prefrontal.

The vomer is an anterior median bone, thickened at the anterior end, but gradually attenuated behind. The bone lies below the parasphenoid, and is joined to it at the posterior part, at the anterior part it is joined to the ethmoid and prefrontals with suture. The ventral surface of the thick anterior end of the vomer is often concave, otherwise nearly flat and is armed with villous teeth. These teeth are grouped generally in a median longitudinal band; but in *Scomber* they are grouped in paired separate patches.

The frontals are large, paired bones, uniting with each other at the median line, and forming a bridge over the orbit, they connect the brain-case with the ethmoidal bones. Their anterior part is thin, flat, and narrow, while the posterior part is broad, and more or less bent downward. From the centre of the dorsal surface of each bone, five striæ radiate in all directions. This central portion is thick. Anteriorly the frontals rest on the entire dorsal surface of the prefrontals and the posterior part of the ethmoid. Posteriorly they articulate with the supraoccipital, parietals, sphenotics, pterotics, and alisphenoids. In the scombroid fishes the frontals do not unite nor meet closely with each other at the posterior end, just above the alisphenoid. In the Scombridæ we find only a slit there, in some fishes of the Cybiidæ the slit is pretty large (figs. 38–40), and in the Plecostei it is large and always conspicuous. Before the slit or foramen the frontals unite with each other at the median line. In the Scombridæ the frontals before the slit are thin, in the Cybiidæ they are thick, and in the Plecostei hollow. In the Thunnidæ near the anterior half of the slit there is a pit with rough walls for the attachment of a ligament connecting the skin to the skull. In the Cybiidæ and Plecostei the lateral external side of the frontal is raised and very thick, while the internal side is raised to form a median crest, continuous to the supraoccipital crest. Thus there is a broad furrow on the dorsal

surface of the bone. This character, however, is not found in *Grammatorcynus*. In the Cybiidæ there is a pair of accessory crests between the temporal and pterotic crests, except in *Sarda* and *Gymnosarda*. And this accessory crest is situated rather near the pterotic crest, and is not so conspicuous as in the Scombridæ.

The alisphenoids are paired bones, forming the anterior part of the floor of the brain-cavity, situated on both sides of the ventral median foramen. Generally they do not meet at the median line, but are separated by a large foramen. They are bounded by the frontals at the anterior end, by the sphenotics at the exterior side, by the prootic and basisphenoid at the posterior end, and by the supraoccipital at the dorsal side in *Gymnosarda* and Plecostei. The alisphenoids of the scombroid fishes never come in contact with the prefrontals, though MASTERMAN (56) states that the alisphenoids of the common European tunny extend from the prooties behind to the prefrontals in front. In the Scombridæ the alisphenoids are a little longer than broad, nearly flat, and separated from the supraoccipital. In the Cybiidæ the inner, anterior end of the alisphenoids is more or less turned downward, and in *Cybium niphonium* (fig. A 2) and *C. koreanum* these bones meet in the anterior median line, and are firmly joined together over the root of the olfactory nerve. In the Thunnidæ (fig. A 3) the inner margin of the alisphenoid is produced downward, and meets with that of the opposite side in the median line, to form a median ventral wall, separating the ventral me ian foramen into two, the small anterior for the olfactory nerve, and the large posterior for the optic. In the Katsuwonidæ the alisphenoids end in a thick pointed process produced along the ventral side of the frontals, and the posterior part is divided into two horizontal sheets. The ventral sheet ends almost free; but in *Euthynnus* it meets with a special broad process of the prootic. In the Cybiidæ and Plecostei the alisphenoid has a dorsal branch at the anterior end. This dorsal branch and the anterior ventral branch grasp the thickened end of the frontal. In the Scombridæ the alisphenoids do not reach the median uniting line of the frontals; but in the Cybiidæ and Plecostei they reach the posterior end of the median uniting line of the frontals and are produced a little further anteriorly below the frontals.

The parasphenoid is a very long bone, running nearly the whole length

of the ventral median line of the skull, connecting the otic region with the ethmoidal bones. At the anterior end it rests on the vomer, and is very firmly united with it, and at the posterior end it is embraced by the ventral sides of the basioccipital. For the most part the parasphenoid is entirely free from other bones. At the anterior part the bone is more or less flattened with a dorsal median ridge, and is united to the prefrontals and ethmoid above. At the posterior end of the free portion, the parasphenoid is rhombic in cross-section, having a ventral median keel. Near the posterior end the bone has two short lateral wings to unite with the prootics. At the posterior end, the bone becomes thin, wide, and is bent upwards at the lateral sides. In the Scombridæ the parasphenoid is very slender, and in full grown forms its posterior end nearly closes the foramen between the two ventral wings of the basioccipital. A sharp ventral median ridge is found underneath the otic region. In the Cybiidæ the parasphenoid is rather broad, forked at the hind end, thus leaving a small narrow foramen, which communicates with the myodome. In the fishes of this family as well as of those of the Scombridæ, the posterior part of the parasphenoid is rather flat. The ventral median keel is scarcely developed, except in *Gymnosarda*. In the Thunnidæ the dorsal median keel of the parasphenoid extends to a spot just below the basisphenoid, and is firmly united to the latter at the end of the keel. Generally there is a small ventral median hole near the posterior end of the parasphenoid. It is remarkable that the parasphenoid is broad in the Plecostei, and is turned upwards at the lateral margin of the posterior part, thus forming a special tubular chamber, characteristic to the Plecostei. The chamber lies below the myodome, and is connected to it with a narrow longitudinal slit. Thus the brain-cavity of the Plecostei is much separated from the base of the cranium. The chamber is narrow and pointed anteriorly, but diverges behind, and ends with an elliptical or roundish opening. In the Katsuwonidæ the dorsal median keel of the parasphenoid is not conspicuous at the posterior end of the orbit. The parasphenoidal chamber is better developed in this family than in the Thunnidæ. In *Auxis* the parasphenoid is produced behind as a pair of long horns beyond the occiput. In the Katsuwonidæ the ventral median keel is better developed than in the Thunnidæ.

The supraoccipital is a median bone more or less elongated longitudinally,

with a well developed occipital crest. The bone is bounded in front by the frontals, and laterally by the parietals, epiotics, and sometimes by the exoccipitals as well. The posterior part of the bone gradually converges, and lies upon the median suture of the epiotics. The posterior slender portion is often extended over the suture of the exoccipitals. This bone has little characteristics in different families.

The parietals are paired flat bones on both sides of the supraoccipital, and rest on the sutural lines between the supraoccipital, sphenotics, epiotics and sometimes pterotics, taking almost no part in the formation of the roof of the brain cavity. The parietals are surrounded in front by frontals, on the outer side by the pterotics, on the inner side by the supraoccipital, and behind by the epiotics. The parietals are rather small, each with a high, longitudinal crest on the dorsal surface. The crest forms a part of the temporal crest, and is continuous to the crest on the frontals in front, and to the epiotic process behind. In the Scombridae the parietals are provided with two crests. In the Cybiidae the parietals are generally separated from the pterotics. In the Thunnidae also the parietals do not unite with the pterotics, at most sometimes touching with a corner above the sphenotics. In the Katsuwonidae the parietals are united to the pterotics at the outer posterior side, and in the genus *Auxis* the whole outer side of the former bone is bordered by the latter, as in this genus the sphenotics do not appear at the dorsal surface of the skull.

The sphenotics form a part of the lateral wall of the optic lobe, and at the same time a part of the dorsal wall of the optic cavity, externally they are a part of the articulating facet for the anterior head of the hyomandibular, moreover forming the postorbital ridge. The sphenotics are bounded externally by the frontals, alisphenoids, prootics, pterotics, parietals, and epiotics, and internally by frontals, alisphenoids, prootics, supraoccipital, and sometimes epiotics. In *Rastrelliger* the parietals and pterotics are also found round the sphenotics. The sphenotics are generally seen at the dorsal side of the skull, between the pterotics and parietals. In the Scombridae the sphenotics are found at the dorsal, external side of the cranium, between the pterotic crests. The internal concavity of these bones is subdivided by a septum. In the Cybiidae the sphenotics are more or less flattened bones and form a very

small part in the lateral wall of the brain-cavity, generally with two concavities. In the Thunnidæ the sphenotic has a large concavity inside, and another large one outside. The latter forms the bottom of a deep pit on the ventral surface of the cranium. The dorsal surface of the sphenotic, lying between the temporal and pterotic crests, is divided into two, by a process of the parietal, extending over these bones and joining the anterior, internal corner of the pterotic. In the Katsuwonidæ the sphenotics are nearly like those of the Thunnidæ; but they appear only a little at the dorsal surface of the cranium between the two lateral crests, or they do not appear at all (*Auxis*). Moreover at their ventral surface, we find a depression at the posterior, internal corner.

The basisphenoid is the smallest cranial bone, Y-shaped, median in position, and lies between the prootics and alisphenoids on the cranial floor. The median vertical process is laterally compressed, and is united to the parasphenoid, thus dividing the mouth of the myodome into two. In the Scombridæ the median process is very long, narrow, but in the Cybiidæ and Plecostei it is rather broad.

The epiotics form the dorsal posterior part of the periotic capsule, lying on both sides of the posterior part of the supraoccipital, and anterior to the exoccipital. They are joined posteriorly to the exoccipitals with a rather straight suture, externally to the pterotics, and anteriorly with the parietals, and sometimes with the sphenotics. In the inner side of the cranial cavity, the epiotics are bounded by the supraoccipital, prootics, and exoccipitals, and sometimes by sphenotics as well. They have each a rough prominent epiotic process to unite with the flat dorsal process of the posttemporal. The epiotic process is continuous to the temporal crest; but in *Scomber* the process and the crest are separate. In the Scombridæ the epiotics are markedly prominent as the external posterior ridge of these bones is vertical as in the Serranidæ and Carangidæ; but in the Cybiidæ and Plecostei the ridge gradually slopes downward and outward. In the Cybiidæ a deep groove or a canal is often found in the internal side of the epiotic to receive the anterior semicircular canal of the auditory organ. In *Katsuwonus* we find a triangular process in the internal side of the epiotic to separate the dorsal part of the anterior semicircular canal.

The pterotics are rather thin, more or less elongated bones, forming the lateral posterior corner of the skull, at the corner the bones are pointed, and more or less produced posteriorly to form the pterotic process. On the ventral surface the bones have a large facette for the articulation of the posterior portion of the hyomandibular. There is a protuberance or a process in the midway of the external margin. Anterior to the protuberance the bone forms the posterior part of the outer cranial crest. In the Scombridæ and Cybiidæ the pterotics are flattened and comparatively narrow in the ventral side, but in the Plecostei a special process is produced at the inner anterior corner of the hyomandibular facette, below the ventral groove of the skull. The lateral posterior corner of the pterotics is much produced in the Katsuwonidæ; but the process is not distinct in many forms of the Cybiidæ.

The prootics are seen from the ventral side of the skull only. They meet very firmly at the ventral median line of the brain-capsule. They are bounded by all the cranial bones of the brain-capsule, except the parietals and the supraoccipital. They are very irregular in shape, and rather large. In these bones we can distinguish two lamellæ, horizontal and vertical. In the Scombridæ and Cybiidæ the vertical lamella is nearly smooth and oblique; but in the Plecostei the vertical lamella is high, more or less twisted, and is moreover divided into two parts. These two parts meet in a line over the foramen jugulare in the Thunnidæ; but in the Katsuwonidæ they are not two independent processes in different planes, and there is no foramen jugulare. These bones form the wall of the medulla oblongata and also receive the ventral and nearly horizontal part of the anterior canal of the auditory organ. Generally speaking the bones are more or less flattened exteriorly, but there are two or three deep grooves on the inner side to receive the greater part of the auditory organ. The foramen jugulare lies upon the horizontal bridge. In the Scombridæ and Cybiidæ the prootics take no part in the formation of the hyomandibular cup.

The exoccipitals correspond without doubt to the neural spine of the vertebra and protect the anterior end of the spinal cord, enclosing the foramen magnum. Each exoccipital has a large paraoccipital condyle. The bones may be seen from the dorsal and ventral sides of the skull. They are bounded by the epiotics, opisthotics, prootics, and basioccipital, and sometimes a little by

the supraoccipital and pterotics.   Each exoccipital diverges anteriorly, and extends also laterally in the Plecost i.   In the Scombridæ and *Grammatorcynus* there is an impression of the clavicular ligament on the bone.   In the Cybiidæ and Plecostei the bone bears, on the dorsal side, an auxiliary intermuscular bone near the foramen magnum, and sometimes another auxiliary one in a little anterior and superior position.   On the ventral side there is a large foramen for the exit of the vagus   In the Katsuwonidæ the exoccipitals are fused at the dorsal margin to form a prominent dorsal median crest, which lies just below the supraoccipital crest.   The exoccipital crest is best developed in *Auxis*.   On the inner side of the exoccipital, there are two or three grooves anterior to the origin of the spinal cord to receive a part of the auditory organ.

The opisthotics are always found in the so-called scombroid fishes, and are generally seen from the dorsal as well as the ventral side of the skull; but in the Scombridæ they do not appear at the dorsal side of the skull, except the articulating knob for the posttemporal.   These bones lie on the exterior side of the exoccipitals, and are bounded by the prootics and pterotics on the anterior and exterior sides.   They form a part of the posterior wall of the brain-case.   They have a large rough process for the articulation of the hollow end of the lower process of the posttemporal on the dorsal side.

The basioccipital is a bone with a concave occipital condyle behind, and a very deep concavity on the opposite side, lying just below the floor of the foramen magnum.   The bone is bounded above by the exoccipitals, in front by the prootics, and ventrally by the parasphenoid.   In the Scombridæ and Cybiidæ it is a narrow bone with nearly parallel horizontal sides in the lateral view.   In the Plecostei the bone is produced ventrally below the horizon of the vertebral column.   This is easily understood if you compare the sideview of skeletons of different families in the accompanying plates.   The expanded lateral wings of the basisphenoid overlap the posterior end of the parasphenoid from outside, protecting the parasphenoidal chamber.

The nasals are more or less elongated flat bones, firmly joined to the anterior margin of the frontals, and the anterior end of these bones rests on the palatines.

The preorbitals are also flat, elongated bones with an articulating surface

at the dorsal margin to fit to a lateral ventral process of the prefrontal. The dorsal margin of these bones is rather thick, but the ventral margin is very thin. These bones protect the lower side of the eyes.

The suborbital ring of bones is more or less conspicuous in the Scombridæ, but in the other groups of the so-called scombroid fishes the ring is inconspicuous, as the bones of the ring are not much differentiated from scales on the cheek.

JAW BONES.

In the Scombroid fishes the premaxillary is a long, curved bone, with a long thick head. The bone becomes gradually narrow behind, and without any marked prominence or groove. In the Scombridæ the bone is very thin, slender, and its head is low and blunt. In the Cybiidæ it is massive, and its head is also low. In that family in general the anterior end of the premaxillary is sharply pointed and the dorsal tip of its head is oblique and pointed. In the Plecostei the anterior head of the premaxillary is large, blunt, and thick, while the remaining part is laterally compressed, and comparatively narrow.

The maxillary is also a long, curved bone with a thick hollow head, lying on the premaxillary. The shaft of the bone is thin and narrow at the posterior end, but thick and grooved at the anterior part. In the Scombridæ the maxillary differs greatly from that of the other scombroid fishes. The head is small, its excavation shallow, while the shaft is uniformly flat and broad, and has an indentation at the posterior ventral margin. The dorsal as well as the ventral margins of the bone are trenchant. In the other scombroid fishes the dorsal margin of the maxillary is generally rounded. In the Cybiidæ the head of the maxillary is generally low, grooved at the ventral side for the greater part, and the posterior end of the shaft is broad and flattened. In the Plecostei the maxillary has the head thicker and larger, and the dorsal margin of the shaft is trenchant in the middle, the ventral margin more or less grooved. The auxiliary bone to the maxillary, called jugal by MASTER-MAN, is very small, narrow, and insignificant in the Scombridæ; but in the other families of the scombroid fishes it is comparatively large and broad. It is pointed at the anterior end and attached to the dorsal posterior corner of the maxillary.

The palatine lies on the external side of the vomer and holds the head of the maxillary fast, with the bent and nearly bifurcated anterior end. In the Scombridæ the bone is nearly flat in the plane of the mesopterygoid; but in the other scombroid fishes its free ventral margin is generally armed with teeth on a ridge, projecting and more or less vertical to the principal part of the palatine, and also to the plane of the mesopterygoid.

The pterygoid is generally a T-shaped bone, united to the palatine with a slender horizontal shaft. The posterior end is expanded and joins to the inner side of the metapterygoid and quadrate, with a rough surface.

The mesopterygoid is a flat thin bone united to the palatine and pterygoid, and rests on the parasphenoid with the internal free margin. It is very remarkable that the bone is armed with an elliptical patch of villous teeth at its centre in the Thunnidæ, as the bone is not armed with teeth in other fishes.

The hyomandibular is a stout bone, with a broad upper portion, and a more or less rod-like lower portion. The broader portion has three conspicuous condyles, of which the anterior and middle are for the cranium, and the posterior one for the opercle. In the Scombridæ the hyomandibular is broad,
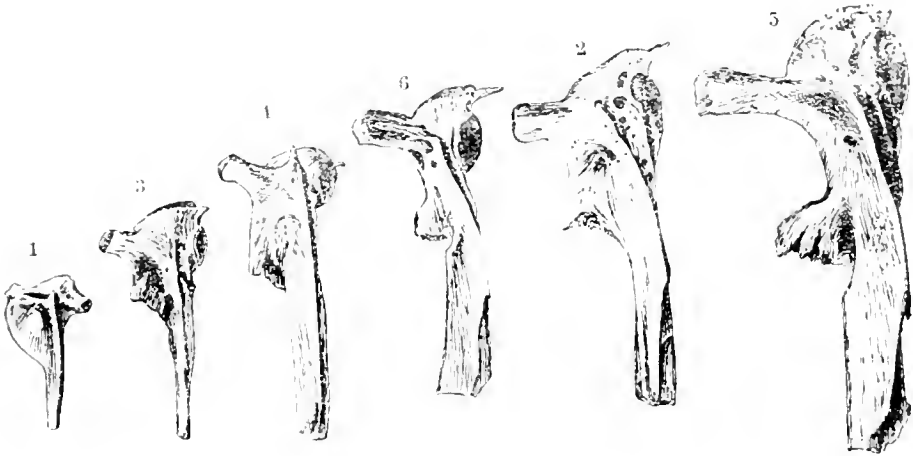
Fig. B. External view of the hyomandibular. 1, *Scomber japonicus*; 2, *Acanthocybium solandri*; 3, *Cybium niphonium*; 4, *Sarda orientalis*; 5, *Neothunnus macropterus*; 6, *Katsuwonus pelamis*.

and the anterior margin of the upper broad portion convex and entire. The condylar protuberances are rather small, not prominent, the anterior one scarcely produced beyond the broad lamellar part, but the posterior one remarkably outstretching behind. Moreover these protuberances are nearly in one plane. The stem of the hyomandibular is grasped by the bifurcated end of the metapterygoid. In the Cybiidæ the upper portion of the hyomandibular becomes narrow, and the anterior condyle is conspicuously produced beyond the lamellar portion. The lower portion is rod-like, and the exterior longitudinal ridge for the attachment of the preopercle is rather prominent, and is produced sometimes beyond the dorsal margin of the broad portion. The posterior condyle approaches the middle condyle, and the former is more or less turned exteriorly. A small pointed process is found behind the middle condyle in the scombroid fishes, except in mackerels. The anterior vertical margin of the upper portion is free; but its lower margin is horizontal and dentate for the articulation with the metapterygoid. In the Plecostei the lamellar portion has become very narrow, but the lower articulating margin for the metapterygoid is broad, so that the lower margin greatly projects. The lower portion is bent a little forward, and is flat and broad, especially in the genus *Auxis*. The exterior posterior longitudinal ridge for the attachment of the preopercle is oblique, and does not reach the dorsal margin of the broad part. The small secondary ridge is developed behind the first, and below the posterior condyle. The last condyle is best developed and is turned exteriorly. The process carrying the anterior condyle is more or less roundish in cross-section in *Thunnus*; but more or less flattened in *Parathunnus* and *Neothunnus*, and in the Katsuwonidæ the process is turned at the dorsal and ventral margins. The lower half of the hyomandibular is broad, flattened, and very thin in the Katsuwonidæ.

The metapterygoid is a broad bone, with the dorsal end bifurcated to grasp the stem of the hyomandibular, and borders the quadrate with a broad, smooth margin, being connected with a narrow intervening cartilage. The shape of the bone differs only a little in different kinds of the scombroid fishes. In *Rastrelliger* this bone is attached to the pterygoid. In *Scomber* the inner branch of the bone extends even over the preopercle. Generally speaking the bifurcation of the bone is not conspicuous in the Cybiidæ. The

metapterygoid and quadrate are firmly connected by the intervention of the pterygoid and symplectic, with which they unite with zigzag sutures at the inner side.

The quadrate is a flat triangular bone, with a stout, movable, saddle-shaped joint at the anterior angle to articulate with the lower jaw. At the lower side there is a shallow groove to receive the lower, anterior portion of the preopercle.

The symplectic is a small bone, styliform at the anterior portion which is wedged into the lower part of the quadrate, more or less flattened at the posterior part, but thickened at the lower margin, and connected with the lower end of hyomandibular by a cartilage.

The articular is a stout bone with a long pointed middle process which is partly sheathed in the dentary, two diverging processes at the dorsal and ventral sides, and a large concave articulating surface for the quadrate, above the knob at the hind end.

The angular is a very small bone, firmly joined to the lower posterior corner of the articular.

The dentary is laterally compressed, forked behind, and always carries only a single row of teeth at the trenchant edge. In the Scombridæ the two branches diverge behind, the lower branch being equal to or a little longer than the upper branch. Moreover the lower branch is broader than the upper in *Scomber*. In the Cybiidæ the bone is comparatively narrow, not diverging, and the lower branch is rather shorter and narrower than the upper, except in *Sarda* and *Gymnosarda*. In these genera and also in the Plecostei the bone diverges; but the lower branch is narrower than the upper, and the two branches are nearly equal in length.

OPERCULAR BONES.

The opercle is a flat bone, more or less trapezoidal in form, articulating to the hyomandibular, and is situated behind the preopercle, and above the subopercle. The opercle is rather larger, as the gill-opening is very wide. The anterior angle of the bone is formed by the articular cup for the hyomandi-bular, and the posterior angle is the dorsal end of the line of union with the subopercle. Generally the dorsal and ventral anterior margins and the diagonal,

Fig. C   External view of the opercle.   1, *Scomber japonicus*; 2. *Cybium niphonium*; 3. *Sarda orientalis*; 4. *Gymnosarda nuda*; 5. *Thunnus orientalis*; 6. *Auxis maru*.
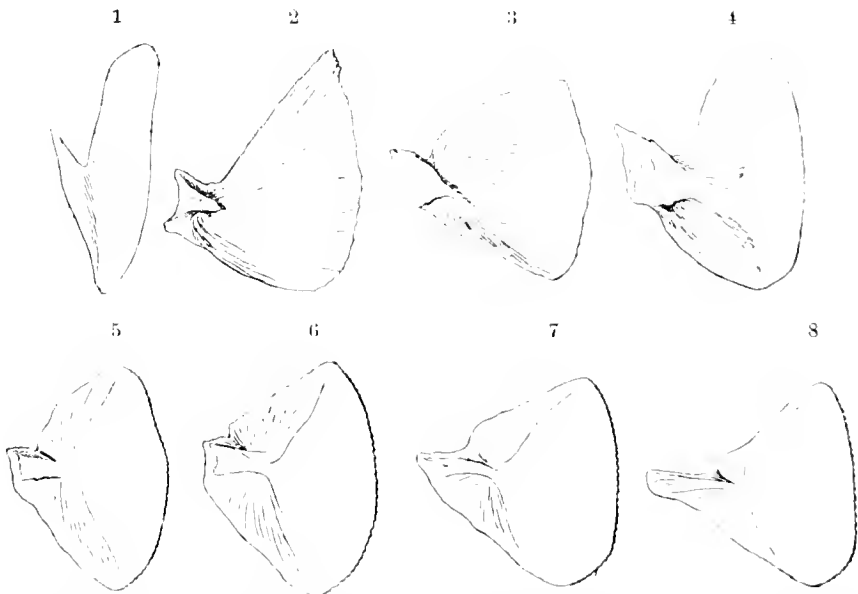
Fig. D.   External view of the subopercle,   1, *Scomber japonicus*; 2. *Cybium niphonium*; 3, *Sarda orientalis*; 4, *Gymnosarda nuda*; 5, *Thunnus orientalis*; 6, *Neothunnus macropterus*; 7, *Katsuwonus pelamis*; 8, *Auxis maru*.

connecting the anterior and posterior angles are strengthened by thick ridges. In the Scombridæ the opercle is thin, rather narrow, and the lower angle is acute, while the upper and posterior angles are rounded. The dorsal posterior side has an indentation just above the posterior angle. The dorsal portion i.e. the portion above the horizontal diagonal is smaller than the ventral portion. The articular cup is more or less rounded with a sharp tooth at the anterior dorsal margin. In the Cybiidæ the opercle is rather broad, and more or less pentagonal. The dorsal portion is smaller and thinner than the ventral. The dorsal angle is rounded, and the posterior sides are more or less serrated. The ventral anterior side is not straight. The articular cup is narrow and elongate. In the Plecostei the opercle is thin but firm, and nearly quadrate in form, so that the dorsal and ventral portions are nearly equal to each other. The dorsal anterior side is concave. The articular cup is ellipsoidal.

The subopercle is more or less triangular, its upper side being overlapped by the opercle, and the anterior side by the interopercle, while the posterior side remains free. In the Scombridæ the subopercle is very narrow, and bifurcated at the dorsal end. The anterior branch is short and pointed. In the Cybiidæ the bone is broad, its anterior branch is also broad and sometimes two-horned, except in *Sarda* and *Gymnosarda*. In the Thunnidæ the anterior branch is abortive and the whole bone is nearly obovate. In *Thunnus orientalis* and also in *Th. thynnus* of the Altantic, the subopercle is more or less crenulated or concave at the anterior margin; but in other tunnies the anterior margin of the subopercle is convex. In the Katsuwonidæ the anterior branch is produced anteriorly and nearly horizontally, ending with a blunt end.

The interopercle is an ovate bone, forming the ventral free margin of the gill-cover with fine serrature. The bone is connected by a ligament to the posterior end of the hyoid arch. The interopercle of *Thunnus orientalis* has its posterior margin convex, while that of the other Japanese tunnies has its posterior margin nearly straight.

The preopercle is a large bent bone, of which the vertical limb fits closely against a groove of the outer margin of the hyomandibular, and the horizontal limb to the metapterygoid and quadrate. In the Scombridæ this

bone is the largest opercular bone, broadest at the middle, and tapering gradually and nearly equally towards both extremities. In the Cybiidæ the horizontal limb is wide near the dorsal end. In the genus *Cybium* the preopercle is very broad at the lower posterior angle. In the Thunnidæ the horizontal limb is well developed; but smaller than the vertical. In the Katsuwonidæ the horizontal limb is better developed than the vertical, and both limbs taper nearly equally towards the extremities. The posterior and ventral margins of the opercular bones are attenuated and roll inward when dried.

Hyoid Arch.

The glossohyal is a small median bone, embedded in the substance of the tongue, with a narrow cartilage at the broad anterior end. In the Scombridæ the bone is especially small, and more or less spatulate. In the Cybiidæ the bone is generally rod-like, thick at the proximal part; but in *Sarda orientalis* it is spatulate. In *Gymnosarda nuda* the glossohyal is nearly covered from both sides with the inner edge of paired semicircular dentigerous ossicles. The front margin of the glossohyal is nearly straight in the Plecostei. In the Thunnidæ the glossohyal is spatulate, slightly concave above and below, and constricted at the posterior end. In the Katsuwonidæ the bone is also spatulate, slightly concave in the cross-section.

The hypohyal forms the symphysis with its fellow of the other side
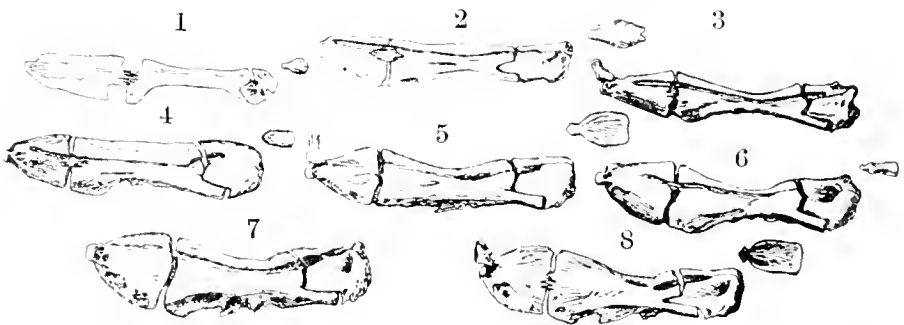
Fig. E. External view of the hyoid arch. 1, *Rastrelliger chrysozonus*; 2, *Scomber japonicus*; 3, *Acanthocybium solandri*; 4, *Cybium niphonium*; 5, *Sarda orientalis*; 6, *Gymnosarda nuda*; 7, *Neothunnus macropterus*; 8, *Katsuwonus pelamis*.

behind the glossohyal, and is composed of two pieces, upper and lower. The former is narrow, while the latter is broad. In the Scombridæ the lower piece has a pair of processes at the posterior margin, growing just in opposition, to grasp the anterior end of the ceratohyal. The inner process is broader than the outer. In the Cybiidæ the lower piece rest partly on the anterior lower process of the ceratohyal. In the genus *Cybium* the posterior upper corner of the upper piece is produced to a pointed process. In the Thunnidæ the upper piece is largely covered by the lower piece from the exterior side. The posterior margin is nearly straight. In the Katsuwonidæ the lower piece has a posterior process which fits tightly to a horizontal slit at the anterior part of the ceratohyal.

The ceratohyal is a long flat bone, broader at the posterior end. Four anterior branchiostegals are attached to this bone. In the Scombridæ and *Cybium*, the dorsal surface of the ceratohyal is nearly straight, while in the other scombroid fishes it is concave.

In the Scombridæ the anterior margin of the ceratohyal is nearly straight; but in the other scombroid fishes this bone has a long process from the anterior lower margin. The ceratohyal is united with the epihyal by means of many fine teeth from both bones, and also the cartilage lying between them. The teeth are larger and more numerous on the inner side. On the external side and near the upper margin there is a narrow groove to receive blood-vessels. In the Cybiidæ the ceratohyal unites with the epihyal by means of long teeth on both the inner and outer sides, except in *Sarda* and *Gymnosarda*. In the latter genera the outer teeth are not found. The groove for blood-vessels is distinct, and sometimes a part of the groove is pierced, as in *Cybium niphonium* and *Gymnosarda nuda*. In the Thunnidæ the tooth-like processes for the articulation with the epihyal are found on the inner side only, as in *Sarda* and *Gymnosarda*. At the ventral margin we find two or three projections, which are inconspicuous in the Cybiidæ. The vascular groove is indistinct, but in *Thunnus* and *Parathunnus* a slit is found in the place. In *Neothunnus* a groove or a slit is hardly visible. In the Katsuwonidæ tooth-like processes for articulation are found on both sides. No slit nor groove is found. Tooth-like processes at the ventral margin are rather conspicuous.

The epihyal is a flat, triangular bone united anteriorly by means of long and fine tooth-like processes with the ceratohyal, and posteriorly with a joint to the stylohyal. This bone carries three branchiostegals. The vascular groove near the upper margin is distinct in the Scombridæ and Cybiidæ; but indistinct in the Plecostei. The bone is short and broad in the Plecostei, especially in the Katsuwonidæ.

The interhyal is a small bone, connecting the hyoid arch through an intervening cartilage with the hyomandibular and the symplectic. In the Scombridæ the bone is styliform, more or less flattened below, in the Cybiidæ broad and more or less flattened, in the Thunnidæ flat, nearly triangular with a lamellar extension on the posterior side, and in the Katsuwonidæ flattened, and more or less rectangular in shape.

The urohyal is a median, laterally compressed, elongated bone gradually widening posteriorly. It is joined to the hypohyals at the anterior end, but free at the posterior end, furnishing a surface for the attachment of the muscle of the isthmus or the throat.

The branchiostegals are flat, slender, curved bones, spanning the membraneous fringe at the mouth of the gill-slit. They are seven in number, and are longer, broader, and more curved posteriorly.

Branchial Arches.

The branchial arches support the gill-lamellæ, and are situated below the cranium, enclosed within the hyoid arch. The general aspect of the branchial arches seems to differ only a little in different groups of the scombroid fishes; but if we examine these arches more closely, the difference among the different groups becomes very distinct (fig. F).

The basibranchials (fig. G) consist of three ossicles in a linear series along the median line. The first is joined to the ceratohyals of the hyoid arch by means of a cartilaginous front end. The second is generally shortest, and the third longest. The second has an oblique groove on each side for the attachment of the first branchial arch. The third ossicle has also an oblique groove for the attachment of the second branchial arch near the anterior end. In the Scombridæ the basibranchials are narrow, laterally compressed, and more or less straight. The grooves for the attachment of

Scomber japonicus   Cybium niphonium   Thunnus orientalis   Katsuwonus pelamis

Fig. I. Dorsal view of the branchial arches, and the side view of a detached gill-raker.

branchial arches do not reach the dorsal margin of basibranchials, so that the upper margin of the basibranchials is higher than that of the branchial arches. In *Scomber japonicus* the first basibranchial is nearly so short as the second, and is bent a little downward. In *Rastrelliger chrysozonus* the first basibranchial is the longest, straight at the dorsal margin, while the second and third are short and nearly equal in length. The third ossicle is bent downward at the posterior half. In the Cybiidæ the grooves for the attachment of branchial arches reach the dorsal margin of the basibranchials. The anterior end of the first basibranchial is more or less thickened. The second is bent downward at the middle. In the Thunnidæ the groove for the attachment of branchial arches are very deep and reach the dorsal margin of the basibranchials. The third basibranchial is horizontally flattened. In the Katsuwonidæ the basibranchials are laterally compressed and narrow. The anterior half of the first basibranchial ascends, and the third is bent downward near the posterior end.

The branchial arches are armed with villous teeth, densely growing on
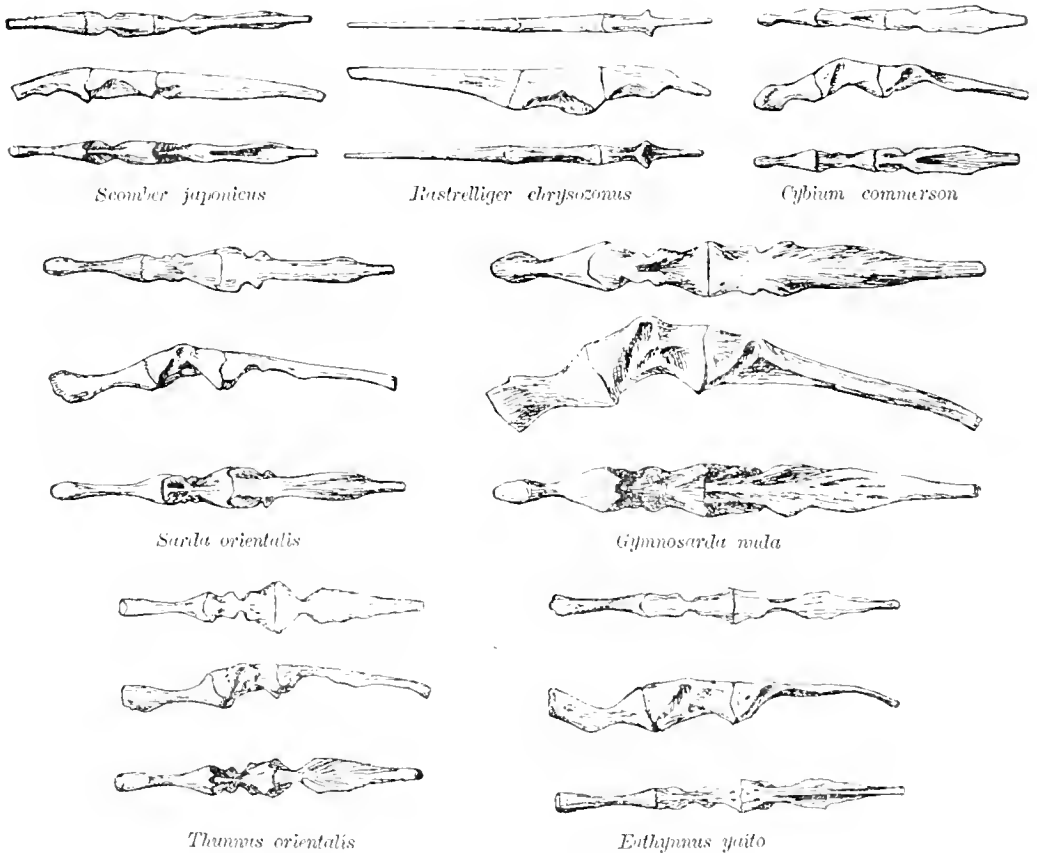
Fig. G. Dorsal, lateral, and ventral views of the basibranchials.

small calcareous pieces on these arches.   In the Scombridæ the upper, anterior
part of the basibranchial ridge is almost naked, being protected with a few
calcareous dentigerous pieces.   The villous teeth on the pharyngeal bones are
nearly equal to those on the branchial arches, contrasting to the coarser teeth
on the former in the other scombroid fishes.   In the Cybiidæ dentigerous pieces
are arranged in two rows, meeting at the dorsal median line of the branchial
arch.   In the Plecostei two rows of dentigerous pieces meet near the internal
corner of the branchial arch.

The hypobranchials are short, joined to the sides of the second and third
basibranchials, and are grooved on the outer or ventral side.   They are not
found in the fourth arch.

The ceratobranchials are very long, subequal in length, more or less curved upward, and grooved on the ventral side. They are narrow in the Scombridæ, and narrow and compressed in the Cybiidæ, especially in *Acanthocybium*. In the Thunnidæ they are more or less compressed at the anterior portion, but rather flattened at the posterior. In the Katsuwonidæ they are more flattened.

The epibranchials are short, much curved, and often twisted. They are rather elongated in the Cybiidæ. The curving and twisting of these ossicles are remarkable in the Scombridæ; but they are rather elongated in the Cybiidæ.

The upper and lower pharyngeals are broad in the Scombridæ, but in the other scombroid fishes they are narrow.

PECTORAL GIRDLE.

The pectoral girdle consists of a series of membrane bones, connected with the skull at the upper part, forming the anterior border of the abdominal cavity, and at the same time supporting the pectoral fin, it receives the hypaxial portion of the lateral muscle from the cephalic region and some succeeding anterior myotomes.

The post-temporal is a small forked bone. The dorsal branch is flattened and rests on the epiotic, while the ventral branch is articulated to a median knob of the opisthotic. The ventral branch is round or oblong in cross-section and hollow at the anterior end. The branch is produced to a short process posteriorly. In the Scombridæ we find a long free bifid process between the dorsal and ventral branches and exterior to the dorsal branch.

In *Acanthocybium* a similar forked auxiliary process is found, partly attached to the exterior side of the dorsal branch. In the other forms of the Cybiidæ, the auxiliary process is not found, and the cross-section of the ventral branch is oblong. The dorsal and ventral processes are connected at their root with a thin lamella. The posterior lamellar portion of the bone is produced forward very little. The interior ridge, continuous to the ventral branch ends with a free point in the genus *Sarda*.

In the Plecostei the post-temporal is well developed, and the interior ridge continuous to the ventral process ends with a free process. In the Thunnidæ the ventral branch is thick and rounded in cross-section. The lamellar portion

has the front margin nearly vertical. In the Katsuwonidæ the lower anterior corner of the lamellar portion is well produced, except in the genus *Euthynnus*.

The supraclavicle is a small elliptical bone, more or less pointed at the anterior end, and thickened at the lower margin. At the anterior part this bone fits between the posterior process and the lamellar portion of the post-temporal. The principal part of the supraclavicle rests on the dorsal extended part of the clavicle. On the inner side of the neck of the supraclavicle a strong ligament, which I shall call the clavicular ligament, is inserted with a broad attachment. The ligament connects the axial skeleton with the pectoral girdle. In the Scombridæ the anterior neck and the exterior vascular groove are not conspicuous; but the inner ventral ridge is well developed. In the Cybiidæ the neck is not distinct, except in *Sarda*, neither is the inner ventral ridge well developed. The vascular groove is faint and found in the anterior median part. In the Thunnidæ the neck and the inner ventral ridge are very conspicuous. The shallow, vascular groove is found at the posterior lower margin. In the Katsuwonidæ the bone is nearly the same as in the preceding family; the vascular groove is deep and conspicuous. In *Euthynnus* and *Auxis*, moreover, a large tendon is inserted just behind the attachment of the clavicular ligament. The tendon is the terminus of a hypaxial small cone of some anterior myotomes, about five in number. Thus the supraclavicle is connected to the axial skeleton with a strong straight, transverse ligament, and indirectly with a hypaxial, longitudinal tendon.

The clavicle is a large curved bone, broad at the dorsal end, thin and pointed at the ventral end. The main stem consists of two wings, the exterior and interior, which meet at the anterior margin. At the dorsal anterior corner there is a pointed process. In the Scombridæ the exterior wing is nearly vertical to the interior wing at the anterior part, and the lower anterior extremity is turned more or less externally. In the Cybiidæ the exterior wing is wide, and is bent backward with an acute angle, and the posterior margin of the exterior wing is parallel to the interior wing. The anterior margin of the bone is mostly rounded. In the Thunnidæ the exterior and interior wings meet in an angle approaching a right angle, and the exterior wing is not well developed at the lower half. The exterior wing is produced interiorly beyond the anterior margin of the bone, at the dorsal part, with the same inclination. In the

Katsuwoni læ the exterior wing is nearly vertical to the interior wing, and there is a groove along the external margin of the exterior wing.

Between the pointed process and the posterior lameller part of the dorsal end of the clavicle there is a narrow slit, through which the transverse clavicular ligament, binding the axial skeleton with the supraclavicle passes. The posterior margin of the pointed process is rounded and smooth. To the clavicular ligament, a small ligament joins running along the anterior margin of the broad dorsal end of the clavicle.

The hypercoracoid is a small flat bone articulated to the clavicle at the upper, interior side, and has a round foramen near the centre of the bone. The hypocoracoid is united to the hypercoracoid above and also to the clavicle at the dorsal anterior corner. In the Scombridæ this bone has an external longitudinal keel, and the lower styliform process is long and narrow. In the Cybiidae the bone is broad and has a median longitudinal groove, or rather the bone is bent externally along the longitudinal axis. The lower process is rather broad. In *Cybium* and *Sarda* the central foramen is very small, but it is large in *Acanthocybium* and *Gymnosarda*. In the Plecostei the lower process is broad, uniformly thin, and folded more deeply than in the Cybiidae. Four actinosts basalia or brachial ossicles are found upon the hypercoracoid and hypocoracoid to support the pectoral fin. They become larger as they approach posteriorly. In the Scombridæ there is no foramen between the last ossicle and the dorsal posterior process of the hypercoracoid; but in all the other scombroid fishes we find a foramen there.
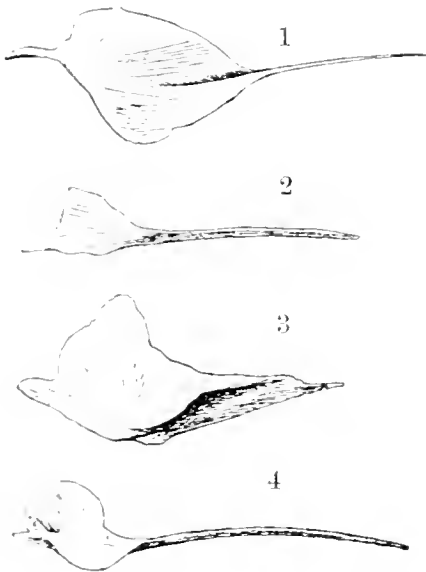
Fig. II. External view of the left lower piece of the postclavicle.

1. *Scomber japonicus*;   2. *Cybium niphonium*.
3. *Thunnus orientalis*;   4. *Katsuwonus pelamis*.

The postclavicle is composed of two pieces of bones, and protects the

dorsal posterior base of the pectoral fin. The upper anterior piece is lamellar, more or less kidney-shaped in outline, and is bent near the ventral posterior end. Its ventral margin concave, and the dorsal convex. The lower posterior piece is rather broad and lamellar at the anterior part, generally with an ascending pointed process, and a long styliform process behind. This lower piece (fig. H) has more characteristics in different forms of fishes than the upper. In the Scombridae the lamelliform portion is comparatively large, and the styliform process suddenly narrows and bends upward. In the Cybiidae the styliform process is rather broad and straight, while the lamelliform portion is rather small and flattened. In the Plecostei the lamelliform portion makes an angle with the styliform. In the Thunnidae the angle or the bent portion is raised and thick, and the styliform portion very short. In the Katsuwonidae the styliform portion seems as if joined to the lamelliform portion, at the inner side near the ventral margin. The styliform portion is long.

PELVIC GIRDLE.

The so-called pelvic girdle is a pair of bones united at the median line, imbedded free in the ventral part of the abdominal wall. Each bone consists of three parts:—anterior, external portion; anterior, internal portion; and posterior styliform portion. The first named portion is largest, and serves for the attachment of muscles. The last two portions meet, with roughened surfaces, their fellows of the other side. The portion of the pelvic girdle where the ventral fins articulate is thick and transverse. The anterior external portion is most well developed and most complicated. In the posterior half of the portion we distinguish three wings;—external, internal, and ventral.

In the Scombridae the pelvic girdle is quite small. The anterior external portion is elongated and bent upward, with its external and internal wings meeting in one plane. The ventral wing is short and small. The anterior internal portion is thin, slender, and has nearly the same length as the ventral wing. The posterior styliform process is also very short. In the Cybiidae the anterior external portion is long and straight, more or less vertical at the anterior part, and the cross-section of the posterior part is triradiate. The anterior internal portion is short and slender, about one-third of the external

Scomber japonicus

Cybium niphonium

Sarda orientalis

Gymnosarda nuda

Thunnus orientalis

Katsuwonus pelamis

Auxis maru

Fig. I. Left external view of the pelvic girdle.

portion in length. The posterior styliform process is rather short. In *Gymnosarda* the external wing of the anterior external portion is turned obliquely towards the external, ventral side, and is not thickened nor folded at the external margin. In the Thunnidae the pelvic girdle is very strongly developed. The anterior external portion is broad, rather thick, and the dorsal exterior margin is also thick and folded. In this family the external and ventral wings of the anterior external portion are nearly in one plane, and the internal wing is united to the middle of the plane, formed by the other two wings. The external wing is folded at the external margin. The anterior internal portion is a little longer than the ventral wing of the anterior external portion. In the Katsuwonidae the pelvic girdle is more specialized. The anterior external portion is thin, and fan-shaped, with a thick external margin. The anterior internal portion is more or less longer than the outer, especially in *Euthynnus* and *Auxis*. The styliform process is very long and laterally compressed. Fin-rays are directly articulated to the thick portion where the three different portions of the arch meet.

Vertebral Column.

The general feature of the vertebral column of the different types of the scombroid fishes may easily be understood by examining Plate XIV, showing the middle transverse section of vertebrae.

In the Scombridae (fig. 30) the number of vertebrae is not large, being 31 in total, and the number of the precaudal vertebrae is nearly the same as that of the caudal. The vertebrae are small, longer than broad, nearly equal in size and form, and are articulated with each other rather loosely by means of short, small zygapophyses. In *Scomber japonicus*, however, the anterior zygapophyses, both superior and inferior, are very broad in the caudal vertebrae, and their anterior margin is divided. The articulating surfaces of the first vertebra with the skull are two, separate, and turned axially, just opposite to the ordinary case. Thus a pair of stout processes at the dorsal corner of the first vertebra grasps the posterior end of the basioccipital (fig. 30, C). The neural spine is nearly equally slender, throughout the whole length of the vertebral column, and the first spine is never free. The anterior concavity of the vertebra is a little shallower than the posterior. The neural and haemal spines are nearly straight, oblique, and generally they are compressed anteroposteriorly. The parapophyses are not developed, and the haemal spine is scarcely developed in the precaudal region. Almost all the precaudal vertebrae have their neural canal divided into two. The lower canal is for the spinal cord, it is entirely covered by a bony roof, separated from the upper canal for the dorsal ligament. The lateral transverse ridge in the anterior precaudal vertebrae is quite peculiar to this family (fig. 7). The last vertebra is not fused with the hypural bones.

In the Cybiidae the total number of vertebrae is very variable, generally over forty. The least number of them in my collection is thirty one in the genus *Grammatorcynus*, and the maximum number sixty four in *Acanthocybium solandri*. The relative number of the precaudal and caudal vertebrae also varies. Generally the precaudal vertebrae are less in number than the caudal. In *Acanthocybium solandri* and *Sarda orientalis*, however, the precaudal vertebrae are more numerous, while in *Sarda chilensis* and *Gymnosarda nuda* the number of vertebrae in both regions is exactly the same. Vertebrae are generally very short, disk-like near both extremities of the body (fig. 41). In most vertebrae

six longitudinal grooves are found;—dorsal median, ventral median, and two pairs of lateral grooves (figs. 8–12). The vertebral column of *Acanthocybium solandri* (figs. 10, 39) and *Cybium koreanum* is different from that of the other forms in having three lateral grooves instead of two. The first neural spine is not always fused to the centrum, nor forms a complete ring at the proximal part, for the spinal cord. In the genus *Sarda*, however, the detachable neural spine of the first vertebra forms a complete ring, being fused at the lower end. Some anterior neural spines are broad and strong. The other neural and haemal spines are slender and weak, and in the middle of the body they unite to the centrum of vertebrae almost perpendicularly at least at their insertion (figs. 39, 41, 42), except in *Cybium chinense* (fig. 40). They are not compressed laterally. The last vertebra is coalesced with the hypural bones and forms a lozenge shaped bone, with a small median notch at the posterior margin. Transverse processes are not developed, but haemal processes and haemal spines of some length are found in many precaudal vertebrae (fig. 38–42). Some of these spines are turned anteriorly in *Cybium niphonium* and *Gymnosarda nuda*. The hypural process of the last haemal spine is notably prominent, and the vertebrae in the caudal peduncle are remarkably small, gradually narrowing backwards, except in the genera *Sarda* and *Gymnosarda*. In these genera the hypural process of the last haemal spine is narrow and the vertebrae of the caudal peduncle are not modified in size, but in form, becoming quadrate prismatic, with their neural and haemal spines broad and flat, as we find in the Plecostei. These spines project backward nearly horizontally, and firmly lay hold of the succeeding vertebra. In these vertebrae the lateral ridges are remarkably developed to the lateral keels (figs. 11, 12). In these cases the two vertebrae preceding the last vertebra are small and flattened anteroposteriorly and are capable of lateral movement. The inferior foramen is developed in some caudal vertebrae; but generally it is small and inconspicuous, especially in the genus *Cybium*. In the superior zygapophyses both the anterior and posterior pairs are large. In the Scombridae and Cybiidae the haemal canal of precaudal vertebrae is suddenly reduced in calibre in some anterior vertebrae. This is due to the exclusion of the cardinal vein from the haemal canal.

In the Plecostei the total number of vertebrae is thirty nine, except in the genus *Katsuwonus*, which has forty-one vertebrae. The vertebrae are articulated

together so firmly that the vertebral column allows little motion to either side. The free lateral motion of the vertebral column is possible only at the root of the caudal fin, where two vertebrae (the last but one and its antecedent) are remarkably thin, and their neural and haemal spines are long, diverging, and flattened at the root. Generally the number of the precaudal vertebrae is nearly equal to that of the caudal. The vertebrae are $18 + 21$ in the Thunnidae, $20 + 21$ in the genus *Katsuwonus*, and in the other genera of the Katsuwonidae $20 + 19$. The relative number of the precaudal and caudal vertebrae is often mistaken, as the haemal spine is also very well developed in the precaudal vertebrae. Moreover, it is remarkable that the haemal spine of some anterior precaudal vertebrae is turned forward in the Thunnidae (figs. 49–52, 64). In *Auxis* the epihaemal spine is also turned forward in the caudal region too. Thus *Katsuwonus* has the same number of caudal vertebrae as the Thunnidae, and the number of the precaudal vertebrae does not differ from that of the other genera of the Katsuwonidae. In GÜNTHER's catalogue less numbers of vertebrae are recorded; but this I am inclined to believe to be erroneous. Vertebrae differ greatly in shape and structure in the different parts of the body. They are much modified near both extremities of the body; but they are comparatively simple and light at the middle. It is noteworthy that the haemal spine is very well developed in some precaudal vertebrae too, so that when ribs are detached it is rather difficult to distinguish them from caudal vertebrae. However the haemal spine of the precaudal vertebrae is broad, thin and laterally compressed at the distal end, for the attachment of ribs, and it is of course shorter than that of the anterior caudal vertebrae. It must be noticed also that the haemal spine of some anterior precaudal vertebrae is turned forward (figs. 49–52). Each vertebra has a pair of short pointed lateral apophyses at the anterior margin of the insertion of the intermuscular bone, especially well developed in the caudal vertebrae. These apophyses serve to keep the intermusculars fast to the vertebrae. The four pairs of zygapophyses are well developed, of which the superior prezygapophyses are best developed. In the Thunnidae the transverse process is well developed in some precaudal vertebrae (figs. 13, 49–52, 64). On the dorsal surface of these transverse processes, the head of the intermuscular bones and ribs are inserted close together, the former preceding the latter. The haemal canal is narrow in *Thunnus* and *Parathunnus*;

but in *Neothunnus* it is nearly equal to or broader than the diameter of the vertebral column, and it is still wider in *Katsuwonus* and *Euthynnus* (figs. 57, g ; 58, g). In the Katsuwonidae the canal is separated from the vertebral column by the development of a peculiar median process which I propose to name as the epihaemal process. These processes as well as the neural, and haemal processes are more or less laterally compressed. The neural and haemal processes are greatly bent backward near the distal end in vertebrae of the middle part of the vertebral column. In *Auxis* the haemal canal is not closed in the precaudal region. In *Thunnus* and *Parathunnus* the haemal canal is closed in the 10th vertebra ; but in *Neothunnus* in the 11th. In the Katsuwonidae the canal is closed still further back :—In *Katsuwonus* 12th, in *Euthynnus* 16th, and in *Auxis* 21st.

In the Thunnidae the first vertebra is very short, and is always anchylosed to the occipital region with a zigzag suture, so firmly that many authors overlooked its centrum, though they found the detachable neural arch belonging to it. The anterior margin of the first neural spine is not straight, but notched. In the vertebrae of the Thunnidae the longitudinal grooves are conspicuous, especially the lateral grooves. The vertebrae are massive, and are finely striated at the surface, and the internal part is alveolar. The inferior foramen as well as the haemal canal are very poorly developed in *Thunnus* and *Parathunnus ;* but in *Neothunnus* they are well developed in caudal vertebrae. In this family the transverse process is developed from the fourth vertebra. It is well developed in the following three to five vertebrae, as a short, nearly flat process with a more or less trenchant edge. In the Katsuwonidae the first vertebra differs but little in size from the following vertebrae, and is less firmly anchylosed to the skull, and at the same time the relation between its centrum and the neural process is much closer, not easily separating from each other. The lateral grooves of the vertebrae communicate with each other near the axis in anterior vertebrae of the precaudal region, and in *Euthynnus* and *Auxis* (fig. 15) the ridges between these grooves are poorly developed or disappearing, thus the vertebral column is much more slender than in the tunnies. The mass of the vertebrae is greatly diminished, as the interior alveolar part is nearly lost, leaving the hard, compact, cortical layer only. The surface of the vertebrae is nearly smooth. The inferior foramen is enormously

developed, and is found in the precaudal region as well in *Katsuwonus* and *Euthyn-nus* (figs. 57, 58); but in *Auxis* the foramen is found poorly developed and in a few posterior caudal vertebrae only.   In this family a pair of special protuberances appear in a few anterior vertebrae.   These protuberances lie just behind the superior zygapophyses, and they serve to furnish points of attachment to a pair of strong tendons of the lateral muscle.

In the Plecostei the neural and haemal spines and other processes from vertebrae for the mutual articulation are well developed.   The neural spine of certain anterior vertebrae is broad and rough for the insertion of muscles, and in bonitos the neural arch of these vertebrae is perforated with numerous pores of different sizes.   The other neural spines are long, slender, laterally compressed, and nearly vertical to the vertebral column at their origin. The haemal spine is remarkably well developed in the precaudal region in tunnies; but in bonitos the spine is scarcely developed in this region. However a median spine of quite new origin makes its appearance in the Katsuwonidae.   It was first described by STARKS (69) under the name of pedicle; but I propose to name it the epihaemal process.   The spine is developed between the centrum and the haemal process or the haemal arch, and is best developed in the posterior part of the precaudal region.   The anterior superior zygapophyses of anterior precaudal vertebrae are long, more or less bent inward at the lower margin in the Thunnidae; but they are more or less triangular pyramidal in the Katsuwonidae, and there is an accessory zyga-pophyses as in the Scombridae.   The anterosuperior zygapophyses in the posterior portion of the vertebral column are elongated and flat, both in the Thunnidae and Katsuwonidae; but in the latter family the accessory zyga-pophyses are formed beneath the ordinary zygapophyses to clasp the posterior superior zygapophyses between these two zygapophyses.   In the Thunnidae the inferior zygapophyses are short and pointed at the end, more or less diverging from the middle of a vertebra, and they do not come into close contact with those of the next vertebra, as in the Cybiidae.   In the Katsuwonidae, however, the inferior zygapophyses of a vertebra are long and in close contact with those of the next vertebrae.

Ribs and Intermuscular Bones.

The ribs are developed along the internal anterior margin of the precaudal myotomes, on both sides of the abdominal cavity, running obliquely backward, to a point where the myotome turns to bend anteriorly. Hence the length and the direction of ribs are determined by the internal boundary lines of the upper portion of the hypaxial half of the lateral muscle. Generally the rib is developed from the third vertebra and is united either directly to the centrum or to the transverse process, or to the distal end of the haemal process or the precaudal haemal spine. Ribs near both extremities of the abdominal cavity are short ; but the other ones are nearly the same in length. They are broad, and form the roof of the abdominal cavity, especially those at the anterior half of the series.

In the Scombridae the ribs are slender, roundish in cross-section, nearly the same in shape and length, separated from each other, and reach quite near the ventral median line (fig. 1). The intermuscular bones form a series of slender bones between the epaxial and hypaxial portions of the lateral muscle, and along the anterior surface of the myotome. They are well developed, slightly curved in anterior precaudal vertebrae, their tips reaching the external surface of the lateral muscle, and are bent backward below the skin. The inter-musculars are developed from the first vertebra to about the twentieth in *Scomber japonicus*. In the latter species the intermuscular bones are inserted just at the base of the haemal arch or process, and seven or eight anterior ones are long enough to appear on the surface of the lateral muscle. The tips of these long intermuscular bones do not overlap each other, and they are at a little distance above the lateral median line of the body (fig. 1). In the other scombroid fishes tips of the intermuscular bones appear at the lateral median line.

In the Cybiidae the ribs are generally slender, subequal, and lie close to, but do not touch each other. In *Acanthocybium solandri* and *Sarda orientalis* some ribs are very broad. Intermuscular bones are found between some cephalic myotomes too, and sometimes we find two pairs in the region, both on the exoccipitals. In the genus *Acanthocybium* the intermuscular bones except the first are attached to the head of ribs, as was observed by STARKS, not on the centrum as in the other scombroid fishes, and in this genus only the first rib is found on the

second vertebra, instead of the third. In this family the tips of long anterior intermuscular bones overlap each other at the external surface of the lateral muscle. In *Cybium* the intermusclar bones are scarcely developed in the caudal region (fig. 6), and the anterior intermuscular bones are turned more or less upward. In other scombroid fishes the intermuscular bones almost lie in one plane. In *Sarda* intermuscular bones are very well developed. They are thick and long in the anterior precaudal region. In *Acanthocybium solandri* the intermuscular bones are ten in number, and are found in the precaudal region only; but in *Sarda* and *Gymnosarda* they are found in the caudal part too.

In the Plecostei the ribs are broad, dorsoventrally compressed, and gradually attenuated towards the posterior, internal side. They lie close to each other and do not hang down along the peritoneum, but they thatch the roof of the abdominal cavity. In the Thunnidae the proximal portion of one or two ribs, lying just before and above the root of the cutaneous artery, is very slender, so as not to obstruct the free passage of the blood. In a large specimen of *Thunnus orientalis* I found that the fifth and sixth ribs consist of two parts. The short, slender, proximal part lies at the anterior slope of the hypaxial portion of the lateral muscle, which is rather suddenly developed from the myotome of the seventh vertebra. These are probably abnormal. The intermuscular bones are developed from the cephalic region to the caudal region, and they are united to the lateral median line of the vertebral column, and each pair at the anterior margin of the centrum of each vertebra, except in the first vertebra, in which these bones are attached to the neural arch. These bones are long, slender, and their distal ends lie at the external surface of the lateral muscle in the anterior part of the body (figs. 2–5); but the majority of them have their distal end at the boundary between the superficial dark red muscle and the profound dark red muscle. The intermuscular bones found anterior to the seventh vertebra are long, and appear on the surface of the lateral muscle, while those posterior to the seventh vertebra become short rather suddenly, and in the case of Katsuwonidae the last two to seven of those intermuscular bones are divided into two portions (fig. 5); the part beyond the profound dark muscle is separate from the proximal part and these two parts are connected with a ligament. Intermuscular bones on the third and fourth vertebrae are fused to the dorsal side of the head of the respective

ribs, and united to those vertebrae. In the Thunnidae the ends of some posterior ribs lie close on both sides of the thick group of interspinous bones of the anal, and in these the posterior pairs of one side run quite near their fellows of the other side.

Interspinous Bones.

In the skeleton of the median fins of the scombroid fishes, we distinguish three types :—(1) that of the first dorsal, (2) that of the second dorsal and anal, and (3) that of the dorsal and anal finlets. Each interspinous bone consists of the distal and proximal segments, and the latter segment is furnished with lateral and sagittal wings. The first interneural is the longest.

In the first dorsal, spines articulate with the proximal segment, behind the wide, dorsally bent distal segment. The posterior end of the proximal segment is also wide and dorsally bent, behind the point of articulation of the dorsal spine. The exterior margin of these dorsally bent parts is often serrated. These dorsally bent parts form the wall of the groove for the first dorsal fin.

In the second dorsal and anal, the interspinous bones are anteroposteriorly compressed, and the divided proximal end of spines or rays grasps the distal segment, and articulates with the proximal segment.

In the region of the finlets, the interspinous bones are elongated anteroposteriorly, often with the development of the middle segment. The distal segment is very small, and is grasped by the proximal ends of fin-rays, and articulates with the proximal segment.

Interspinous bones of the first dorsal and finlets are generally found one of each in each myotome, but those of the second dorsal and anal are generally two in each myotome. No spurious interspinous bones before the first dorsal. The interspinous bone of the last finlet of the dorsal and anal wants the proximal segment, and is attached to the posterior end of the proximal segment of the preceding finlet.

In the Scombridae the interspinous bones are weak and narrow, and there are some spurious bones between the two dorsals, one in every myotome, and the free lower end of the interspinous bones of the first dorsal are inserted between the tip of the neural spine of precaudal vertebrae. The anterior

interspinous bones are inserted more than posterior ones. In *Restralliger* the interspinous bones carrying finlets have their sagittal wings well developed.

In the Cybiidae the lateral wings of the first dorsal interspinous bone gradually narrow towards the dorsal end. The distal segment of the first dorsal interspinous bone is a very small round ossicle. Anterior interspinous bones are oblique, but those behind the middle of the vertebral column are more or less vertical.

In the Plecostei (fig. 44) the first dorsal interspinous bone is very well developed with the lateral wings turned anteriorly, and the anterior sagittal wing is very broad, but the lower part not developed, terminating at the middle of the lateral wings at the axis. The distal segment in the first dorsal is broad and turned over upward, and the dorsal posterior end of the proximal segment is also expanded laterally, except a few anterior interspinous bones. These expanded parts are turned up, quite like the distal segments. Some posterior interspinous bones of the first dorsal are laterally compressed and want the lateral wings. In the second dorsal proper the interspinous bones are compressed anteroposteriorly and two of them are generally found in every myotome, instead of one in the first dorsal. In the Carangidae two or three interspinous bones are found in one myotome under the first dorsal. In each interspinous bone the lateral wings are better developed than the sagittal wings. In the second dorsal the distal segment is a small narrow bone, inserted between the bases of the two moieties of each fin-ray. The exterior margin of the lateral wings is strengthened by the development of accessory ridges. The interspinous bones of the anal fin differ more or less from those of the second dorsal, and resemble rather the first dorsal. The first ventral interspinous bone is longer than the succeeding bones, and some anterior ones are fused together. Most of them have wide lateral wings but the sagittal wings are not well developed. The lateral wings increase in width towards the free end, and suddenly converge toward the pointed extremity. Two of these interspinous bones are found in every myotome. Interspinous bones of the finlets are quite alike in the dorsal and anal. They are more or less rod-like in the Thunnidae; but they have lateral as well as sagittal wings in the Katsuwonidae, and in the posterior part the sagittal wings only are developed. The distal segment of the interspinous bones of the second dorsal and anal is very small,

and is inserted between the two moieties of the fin-ray.

The lateral margin of the distal segments and that of the dorsal posterior end of the proximal segment are mostly serrated in the Thunnidae, but is straight and entire in the Katsuwonidae.

MUSCULAR SYSTEM.

I have chiefly examined the lateral muscle, the other muscles were scarcely touched. The great lateral muscle is originally composed of as many transverse segments as there are vertebrae, and each segment is attached internally to the respective vertebra and its processes and appendages,—neural and haemal processes, ribs, and intermuscular bones. The first three muscle-segments, however, do not correspond to the first three vertebrae, as these three segments belong to the cephalic, or rather occipital region, where we find one or two auxiliary intermuscular bones between them, in the Cybiidae and Plecostei. These cephalic myotomes are inserted between the foramen magnum and the pterotic processes of the cranium, and connects the skull with the pectoral girdle. Hence the fourth muscle-segment or myotome corresponds to the body-segment of the first vertebra. Moreover, some myotomes seem sometimes to augment by subdivision, in fishes of the Katsuwonidae. In *Auxis* one or two auxiliary myotomes are added in the hypaxial half. Generally one auxiliary myotome is added near the boundary between the precaudal and caudal portions. When there is another auxiliary myotome, it is found in the anterior part of the precaudal region, where the cutaneous artery appears to the surface of the body. These auxiliary myotomes are not always bilaterally symmetrical. Moreover two auxiliary myotomes are sometimes found in one side, and only one in the other. At the caudal region some myotomes are coalesced and they are much elongated anteriorly. The myotomes in the caudal peduncle are united into one in the Plecostei, in the region where the lateral keel makes its appearence in the vertebrae, and where the neural and haemal processes are broad and horizontal. Thus in the anterior part of the adult fish, the number of myotomes is greater than that of the vertebrae, and in the caudal region the number is reduced from the confluence. The cephalic myotomes as well as some following myotomes project anteriorly as a triangular mass, and their thin, dorsal limb is bent forwards along the dorsal median

line over the cranium. In the Plecostei each myotome faithfully follows the
course of the neural and haemal processes to their ends, at the median long-
itudinal plane, not separating from them on the way, as is found in some
teleostean fishes. Each myotome is bent in a zigzag line on the surface of
the body, and may be separated into four parts, right, left, dorsal or epaxial,
and ventral or hypaxial. The two lateral halves of the myotome are well
separated by a thick membrane, aponeurosis, spun on the axial skeleton and
its processes, and by the abdominal cavity. The membrane is very thick
in the Plecostei. The dorsal and ventral portions are separated by a
membrane of connective-tissue, connecting intermuscular bones, tendons, and
ligaments.

In the Teleostei muscle-fibres are generally well discernible from outside
even in the last myotome (except in the genus *Sarda*); but in the Plecostei
many caudal myotomes are changed to tendons at the posterior, external surface
(fig, 3). Therefore the extremity of the caudal portion looks bluish, when the
skin is removed. In the Plecostei nearly eight last myotomes seem to be
fused into one. In *Auxis* the tendon of the last myotome is enormously
elongated anteriorly, reaching far beyond the anus, to about the middle of the
17th myotome (fig. 2).

The muscular system, as may be supposed from other structures, is well
developed and much complicated in the Plecostei and allied fishes. The course
of the myotome runs at its external surface from the dorsal median line sharply
backward, then gently forward, and gently a little backward to the lateral
median line; in the ventral half slightly forward, then, gently backward, and
lastly sharply forward (fig. 3). The backward bend at the lateral median
line is noteworthy in these fishes, in more primitive fishes the bend is not
found at all. The bend is sharper in the anterior portion than in the posterior
portion of the body. Indeed the zigzag course at the surface becomes more sharply
bent as the position of the fish advances higher, and at the same time the conical
forward outgrowth of the myotome is more elongated. The epaxial conical
outgrowth is longer than the hypaxial, and is much more reduced in thickness.
Therefore we find many concentric circles of myotomes in the cross-section of the
lateral muscle, 3 or 4 in the Scombridae, about 10 in the Cybiidae, and 10–
16 in the Plecostei (figs. 16–19). The backward bend of myotomes in the

epaxial and hypaxial portions has some breadth in the Scombridæ and Cybiidæ (fig. 6), therefore we find two parallel traces of connective-tissue fibres, which connect firmly with the vertical aponeurosis, ensheathing the axial skeleton from both sides of it, just at the end of the neural and hæmal processes, where the myotomes are very sharply bent. In the Plecostei, however, myotomes are very thin at the points of external bending and they are inserted to the axial skeleton at one line of traces. In *Cybium* the number of cones of myotomes in cross-section of the lateral muscle is only a little more numerous than in *Scomber*, but in *Sarda* the number is almost as many as in the Thunnidæ. At the anterior end of the body the apex of the cones is nearer the axis than to the surface of the body; but in the caudal portion it gradually approaches the surface. In the Katsuwonidæ (fig. 19) a part of some anterior myotomes envelopes a large tendinous chord from the second vertebra, or rather a part of some anterior myotomes forms a small auxiliary cone of concentric myotomes, which ends in a strong tendon attached to the second vertebra. In *Euthynnus* and *Auxis* another smaller auxiliary cone of myotomes round a tendon is inserted into the supraclavicle (fig. 2).

In the Scombridæ and Cybiidæ and also in the Katsuwonidæ the dorsal and ventral limbs of the myotome are more or less wide at the insertion into the median septum; but in the Thunnidæ the dorsal and ventral limbs of the myotome are very thin.

The dorsal limb of some anterior myotomes always reaches the front margin of the frontals in the Plecostei, but in the Teleostei it is not always the case.

In fishes the median superficial lateral muscle is generally darker in colour. Its extent is sometimes very well defined, but sometimes more or less indistinct. It is thin and narrow at the anterior part, but thick and wide at the posterior. This dark coloured portion is triangular in cross-section, and is bounded by membranes of connective tissue, which are united to the line connecting the distal end of intermuscular bones. In the Teleostei tendons of the great lateral muscle are mostly found in the superficial dark coloured portion; but in the Plecostei they are found in deeply seated dark coloured muscles. The deeply seated dark red portion of the lateral muscle is characteristic to the Plecostei. It is called "chiai" or "chimi" in our country, from very old times. In 1712 Ryonan Terajima described "chiai" as being found

in two bands in bonitos and tunnies, and being inferior in taste to the ordinary muscles. In the Plecostei the ordinary flesh is remarkably reddish, as the special superficial segmentary canals send a copious flow of blood into it (fig. 3). The dark colour of the median superficial muscle is due to the rich supply of blood from segmentary arteries along the intermuscular bones. The darker colour of the "chiai" portion is also due to the same cause, but from a different source.

In the Plecostei as the ordinary muscles are red coloured, the median superficial muscle as well as the deeply seated portion round the axial skeleton are nearly blackish red as they receive more blood than the ordinary muscle. The blackish red portion scarcely reaches the centre of the concentric circles in the cross-section of the lateral muscle. In tunnies the blackish red portion does not reach the vertebral column in the epaxial portion, but in the hypaxial portion it always reaches. This is well marked in the posterior portion of the body. The blackish red portion is thin and flat at the anterior part of the body, it then becomes gradually thick, thickest at the posterior part of the precaudal region and then being compressed laterally moves towards the surface together with the centre of the concentric circles in the cross-section. The boundary of the "chiai" portion is quite distinct. In the process of curing, the curer observes that the "chiai" portion is liable to separate from the surrounding portion. In the Katsuwonidae the epaxial portion also reaches the axial skeleton (fig. 19), and the hypaxial portion has a wide base for the insertion to the axial skeleton as the dorsal aorta which supplies blood to the "chiai" portion is more or less separated from the vertebral column by the development of the epihaemal process. In this family the posterior part of the superficial lateral muscle is not so dark as the deeper layer. This is due to the fineness of the cutaneous artery in the posterior part. The shape and volume of the "chiai" portion vary in different species. In the Thunnidae, *Thunnus orientalis* has a comparatively large voluminous dark red portion, but *Neothunnus macropterus* has a small quantity of the dark red portion. In the Katsuwonidae the quantity of dark red portion is comparatively large, especially in *Auxis* which has about one fourth of the lateral muscle dark coloured. In the "chiai" portion tendons are well developed, especially in the epaxial portion and in the caudal portion (fig. 2). In the Teleostei the most active part of the lateral muscle seems to

be the median superficial part, while in the Plecostei it seems to be the deeply seated "chiai" portion. In the Teleostei the dark coloured portion gradually becomes broader and thicker in the caudal portion, passing beyond the limit of the median superficial lateral muscle. I have examined and found that the dark red portion contains about 7 times as much blood as the other portion in *Thunnus orientalis*, and about 15 times as much as in *Parathunnus mebachi*. In *Scomber japonicus* the superficial red muscle contains almost 8 times as much blood as the other flesh, and in *Cybium niphonium* the superficial red muscle contains 12-13 times as much blood as the ordinary flesh, which is nearly colourless.

Histologically the dark red portion consists of uniform and fine fascicles, with many capillaries among them, and their muscle-fibres are faintly striated, more or less resembling the involuntary muscle-fibres. When the dried muscle of tunnies or bonitos are broken transversely, the chiai portion is rather rough and not lustrous, while the other portion is quite smooth and conchoidal.

In the Katsuwonidae the chiai portion is better developed than in the Thunnidae, and both the epaxial and hypaxial parts of it reach the vertebral column, as the chiai portion has a wider base than in the tunnies, and as the segmental blood-vessels nourishing the portion originate on each side of the dorsal aorta and its plexus at two points, a little above and more or less below the vertebral column.

To the ventral side of the vertebral column a pair of cylindrical muscles are inserted to suspend the pharynx. These muscles run obliquely forwards from the vertebral column. These pharyngeal muscles are inserted into the 3rd and 4th vertebrae in *Scomber japonicus*, to the 4th in *Rastrelliger chrysozonus*, to the 3rd
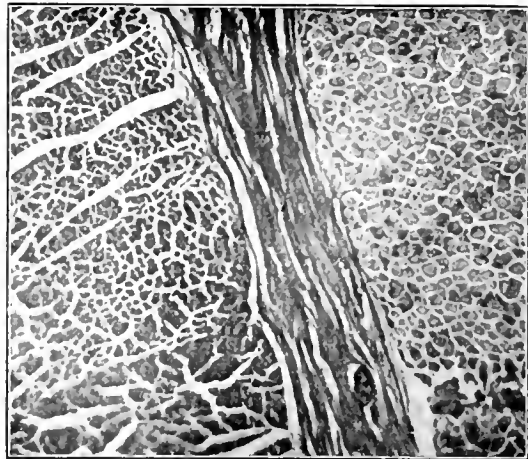
Dark red portion   *Vascular plexus*

Fig. J. Cross section of the lateral muscle, showing the large fascicles of the ordinary portion on the right side, and fine dark coloured fascicles of the dark red portion on the left.

in *Grammatorcynus bilineatus*, to the 6th in *Cybium niphonium*, to the 5th and 6th in *Sarda orientalis*, to the 5th in *Gymnosarda nuda*, to the 5th in *Thunnus germo*, to the 5th and 6th in *Thunnus orientalis* and *Neothunnus macropterus*, and to the 6th in *Parathunnus mebachi* and *Auxis*.

In the Scombridae and Cybiidae weak short slender tendons are developed from the root of each horizontal apophysis obliquely forward along the border of each myotome and are firmly attached to the ventral side of the distal end of the preceding apophysis and intersect with ligaments running along those processes. In the Plecostei these tendons are much better developed, being longer and more obliquely inclined, especially at the anterior and posterior ends of the body. These tendons are split into two sheets of fine fibres at the apex of the intermuscular bones, and the sheets run dorsalward along the axial sides of the superficial dark coloured muscle. These sheets are transformed to the myocommata. The lateral tendons are not found from the middle part of the lateral keel in the caudal portion.

Dr. NORIO OGATA (58) found that the alcoholic extract from the chiai portion of the muscle is valuable as an antigen in WASSERMANN's reaction for syphilis. In the Thunnidae the dorsal anterior end of the stomach is connected with the roof of the body-cavity by means of a short, slender, median muscle.

In the teleostean fishes the quantity of flesh amounts to less than sixty percent of the total weight of the body, but in the Plecostei it is more than seventy percent, especially abundant in *Thunnus germo*, as in this species the dorsal wall of the abdominal cavity is convex. This abundance of flesh is due to the narrowness of the visceral cavity, or the great development of the hypaxial portion of muscle in the precaudal region. Mr. G. YUASA of the Los Angeles Sea Food Packing Co. told me that 1 ton of *Thunnus germo* produces 45 cases of canned meat, while from *Neothunnus macropterus* only 37 cases are produced.

LIGAMENTS AND TENDONS.

As the so-called scombroid fishes are generally active swimmers, they are rich in ligaments and tendons, which are best developed and most complicated in the Plecostei. A well developed ligament generally present in teleostomatous fishes connects the shoulder-girdle with the axial skeleton. I shall distinguish

this ligament under the name of the clavicular ligament. It is inserted to the inner side of the supraclavicle at one end, and to the occipital region or to one of the anterior vertebrae at the other. Another ligament, commonly found in the teleostean fishes is long, situated in the spinal canal, above the spinal cord, thus connecting the vertebrae. A short median ligament connecting the skin in the head to the frontals is peculiar to the Thunnidae. A pair of thin and short ligaments is found between the first and second vertebrae in the genus *Auxis*. Besides these there are many ligaments connecting different parts of the skeleton.

Tendons are well developed near both ends of the body, especially near the tail, and in the fishes of the Katuwonidae. A longitudinal tendon running from the tail and forming the axis of a large muscular cone is very long in *Auxis* (fig. 2). In this genus two tendons forming the anterior extremities of the two hypaxial cones of myotomes just below the median septum between the epaxial and hypaxial portions of the lateral muscle are remarkable. The external tendon is attached to the supraclavicle, just behind the attachment of the clavicular ligament, and the internal to the large lateral tubercle of the second vertebra. Between every two body-segments we find a pair of tendons. These tendons connect the intermuscular bones, and are joined at the abaxial end to the myocommata. In the teleostean fishes these tendons are simple, but in the plecostean fishes they are longer and much more complicated, as they make more acute angles with the vertebral column.

NERVOUS SYSTEM AND SENSE ORGANS.

The brain-cavity of the scombroid fishes is small as in other teleostomatous fishes, and the brain does not occupy even the whole of this small cavity, being surrounded by a thick layer of a fatty substance. Thus even a tunny of ca 40 kg has a brain as small as a man's thumb. The brain of the scombroid fishes does not differ much from the common type of the brain of the Teleostomi. The enormous development of the optical lobe and cerebellum is striking. The nondevelopment of the cerebral hemisphere is also remarkable. In the Plecostei the optical lobe has a very large groove on the ventral side, as if the lobe is made by folding, when seen from that side. The groove is especially remarkable in *Auxis*, in which a corresponding groove is found in the

ventral side of the skull, in the otic region.
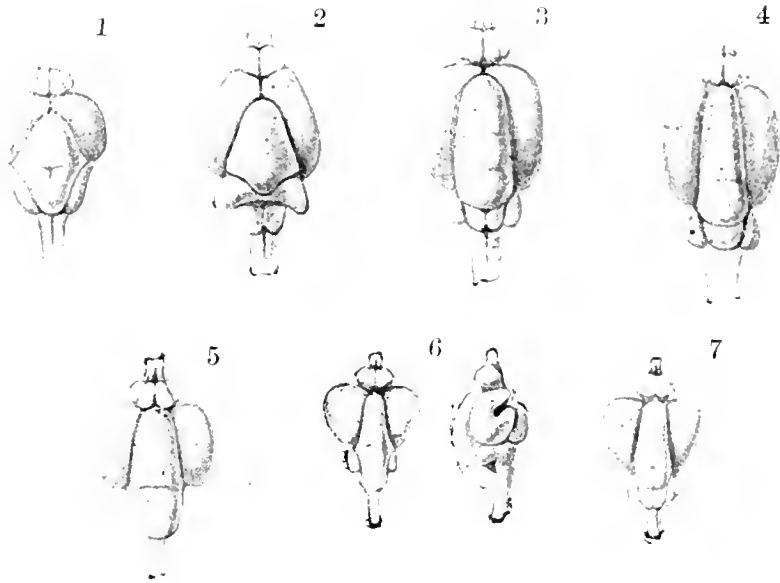
Fig. K.   Dorsal view of the brain.

1, *Scomber japonicus*; 2, *Cybium niphonium*; 3, *Thunnus orientalis*; 4, *Thunnus germo*;
5, *Katsuwonus pelamis*; 6, *Auxis maru* (dorsal & lateral); 7, *Euthynnus yaito*.

In the Plecostei the brain is thicker than that of the Teleostei, and the cerebellum covers the whole length of the brain, behind the prosencephalon. The external surface of the prosencephalon and cerebellum is not flat. The former is divided into four longitudinal lobes, and the latter into several areas by the median longitudinal and transverse grooves.

Ganglia of the sympathetic nerve are found in the haemal canal, one in each body-segment, and when the canal is filled with the vascular plexus, they are embedded in it.

The otolith is rather thick and the parts on each side of the median groove are nearly equal in the Scombridae.   In the Cybiidae one side is longer than the other, and in *Gymnosarda* the longer side is very much elongated and is nearly twice the length of the other.   In the Thunnidae the otolith is straight, and one side is much longer than the other.   In the Katsuwonidae the otolith is very slender and the parts on both sides of the groove are equally well developed, the hind end being more or less swollen.

The olfactory organs are a pair of grooves in front of the eyes. Each groove or sac communicates with the exterior by a pair of pores, nostrils. The anterior nostril is generally small, while the posterior is more or less elongated, oblong in the Cybiidae, and quite a slit in the Scombridae and Plecostei. Beneath the anterior nostril, there is a group of olfactory leaves, about 30 in number, arranged radially, in the form of a rosette. In the Scombridae two nostrils are situated rather near each other, and the upper wall of the olfactory cavity is uniformly thin. There is a deep groove in the floor of the cavity before the ethmoid, and just behind the olfactory rosette. The cavity extends behind the groove. The inner opening of the posterior nostril lies above the groove or before it.

In the Cybiidae the olfactory cavity is rather small, and the two nostrils are close together, the whole cavity is nearly filled with the rosette of the olfactory leaves. In this family the posterior nostril lies more or less behind the rosette. The dorsal wall of the cavity is thin, but the border of the inner orifice of the posterior nostril is generally raised. Moreover the dorsal wall is thickened in *Sarda*. Generally the cavity does not extend behind the posterior nostril, and there is a fleshy dam behind the rosette and below the posterior nostril.

In the Thunnidae there is a space behind the rosette, thus the two nostrils are much separated. The anterior nostril is very minute. The rosette of the olfactory leaves is high and occupies the whole height of the cavity. The dorsal wall of the cavity is very thick.

In the Katsuwonidae the two nostrils are close together, and the cavity is much more depressed than in the Thunnidae. The passage of the anterior nostril is almost perpendicular to the surface of the head, while that of the posterior is more or less turned obliquely. The former has the uniform calibre, but the latter is wide at the inner orifice, and becomes gradually narrow towards the outer orifice. Between these nostrils there is a narrow groove on the roof of the olfactory cavity.

ABDOMINAL CAVITY.

In the Scombridae the height of the abdominal cavity is more than half the height of the body, and the cavity lies just beneath the vertebral column ;

but in the Cybiidae the cavity is more or less separated from the vertebral
column, from the development of the haemal processes in many precaudal
vertebrae. In the the Plecostei the coelomic cavity is low and narrow, as the
haemal process of precaudal vertebrae is much better developed than in the
Cybiidae. The height of the cavity is less than its breadth, and its roof is
flat or convex, thatched with a broad proximal portion of ribs, and protected
by the peritoneum, composed of thick bundles of connective tissue arising from
the distal end of the precaudal haemal spines, and interwoven with each other
at their root. These bundles of connective tissue are inserted at the ventral
median line of the cavity, here too, their ends are interwoven. Generally
speaking the visceral cavity of the scombroid fishes does not extend to the
caudal portion, though some posterior ribs push their way into the lateral
muscle, beyond the peritoneum, and lie on each side of the interhaemals. Thus
the length of the abdominal cavity may approximately be known by measuring
the distance of the anus from the gill-slit. In the genus *Auxis*, however, the
genital gland extends beyond the origin of the anal, and grasps the inter-
haemals of the fin from both sides. Thus the abdominal cavity is also extended
backward beyond the anus with the genital glands.

In the Scombridae the peritoneum is often dark coloured as in *Rastrelliger*
and immature forms of *Scomber* probably owing to the body being broad, and
abdominal wall thin, nearly vertical, and the light seems to transmit more or
less; but in adult forms of *Scomber*, Cybiidae, and Plecostei the peritoneum is
little affected by the light, as the abdominal wall is thick and is turned
obliquely downwards. Thus the peritoneum remains nearly colourless in these
groups. The peritoneum is developed round the visceral organs and envelops
them, and the generative organs, rectum, etc. are suspended from the dorsal
wall of the body-cavity by the peritoneum. The peritoneum is very thick at
the posterior part of the body-cavity in *Thunnus germo*.

AIR-BLADDER.

The air-bladder is sometimes present and sometimes absent, and this is the
case even among species of the same genus. The air-bladder is generally
absent in those fishes living always near the surface of the sea. Thus it is
entirely wanting in the fishes of the Katsuwonidae. It is, however, rather

difficult to understand that *Acanthocybium* which is always found near the surface has a well developed air-bladder, while *Cybium niphonium* which has a rather wide range of vertical distribution lacks it. The air-bladder is more or less fusiform, and generally thickened at the anterior part.

In the Scombridae the air-bladder is generally present, being absent in *Scomber scombrus* only. In *Scomber japonicus* the air-bladder is fusiform, narrow and pointed at both ends. It occupies a little more than half the length of the abdominal cavity. Its wall is very thin.

In the Cybiidae the air-bladder is not found in *Cybium niphonium*, *C. koreanum*, and *Sarda orientalis*. In *Gymnosarda unda* the air-bladder is large and thick-walled.
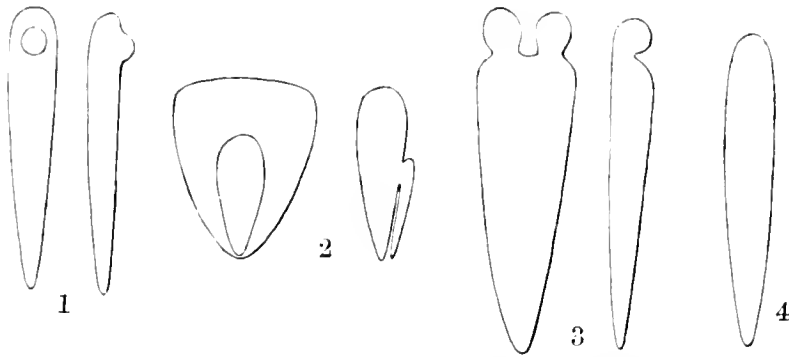
Fig. L. Air-bladder of tunnies. 1, *Thunnus germo* (dorsal and side views); 2, *Thunnus orientalis* (dorsal and side views); 3, *Parathunnus mebachi* (dorsal and side views); 4, *Neothunnus macropterus* (ventral view).

In the Thunnidae the development of the air-bladder is very interesting. In *Thunnus germo* the air-bladder is narrow, but long, running the whole length of the abdominal cavity, and has a median dorsal swelling at the anterior end. In *Thunnus orientalis* the air-bladder is triangular, very wide, and straight at the anterior end, occupying the entire breadth of the abdominal cavity, but it is short, and becomes gradually narrow behind, pointed at the posterior end. It is a little longer than half the length of the abdominal cavity. The external wall is uniformly thin. The internal wall is finely reticulated. At the middle of the roof of the air-bladder, there is a large round hole, which leads to an accessory conical cavity, extending from the hole behind to the

posterior end of the principal cavity. At the anterior end of this upper accessory cavity a vein pours to a segmentary vein. In immature tunnies the air-bladder is very small, and almost collapsed. The air-bladder of this species has a pair of slight swellings along the anterior side.

In *Parathunnus mebachi* the air-bladder is a little narrower than the roof of the abdominal cavity; but occupies the entire length of the cavity, at the anterior end the air-bladder is divided into two large coeca, by the dorsal aorta in the middle, and is separated by the cutaneous arteries from the principal cavity. The internal wall is finely reticulated.

In *Neothunnus macropterus* the air-bladder is narrow, and is protected by a very thick mass of connective tissue from the ventral side. This thick mass of connective tissue is utilized as a material in making glue. On the middle of the dorsal wall a large vein is found with radiating venules from all sides.

The red gland is developed at the anterior part of the air-bladder, near the point where the artery for the air-bladder enters. The air-bladder of the Scombridae and Cybiidae receives blood from the dorsal aorta at several points, and pours its venous blood to the posterior cardinal vein at several spots; but in the Plecostei the arterial blood is received from a special branch of an artery, running along the right hand side of the stomach, and the venous blood pours to the caudal or the posterior cardinal vein through a segmental vein. Thus the arterial system of the air-bladder belongs to the axial system in the Scombridae and Cybiidae, but to the visceral system in the Plecostei.

DIGESTIVE SYSTEM.

The mouth-cavity is black in the Scombridae, black or greyish in the Cybiidae and Thunnidae, and silvery or colourless in the Katsuwonidae. The tongue is small, narrow, and black in colour, and far behind the symphysis of the lower jaw in the Scombridae; broad, flat, and generally greyish in the Cybiidae; greyish in the Thunnidae; and silvery white, medium in size, and the membrane at the lateral margins is turned upward in the Katsuwonidae. The surface of the tongue is granulated in the genus *Scomber*, armed with villous teeth in *Gymnosarda* and Thunnidae, and quite smooth in *Acanthocybium*, in many species of the genus *Cybium*, and in the fishes of the Katsuwonidae.

The development of the gill-rakers on the branchial arches has a close

relation with the nature of food.   The gill-rakers are strainers, and chiefly serve
to prevent the escape of food from the branchial cleft, thus they are best developed
in the plankton-feeders, such as mackerels and bonitos ; but they are poorly de-
veloped in voracious forms, such as scorfishes, and are entirely wanting in.
Acanthocybium.   At the same time the gill-rakers may serve "to prevent any
solid particles from passing into the gill-clefts and clogging or otherwise injuring
the branchial filaments."   Gill-rakers are best developed on the external side of
the first branchial arch.   They are long and bar the space between the opercle
and the branchial arch.   Other series of gill-rakers are developed on the inter-
nal side and bar the intervals between branchial arches or the interval between
the branchial arch and the lower pharyngeals.   Gill-rakers on the external side
of the branchial arch are directed forward, while those on the internal side are
directed backward.   Gill-rakers lie close to the branchial arch when the mouth
is closed ; but are separated and make angles with the branchial arch, when
the mouth is open.   The inner or upper side of the gill-rakers is rough, armed
with minute tooth-like prickles.

In the Katsuwonidae the gill-rakers on the internal side of the branchial
arches are well developed.   The good development of gill-rakers on the upper
arm of the first and second branchial arches is remarkable.

In the Scombridae the gill-rakers are weak, longer than the gill-lamellae,
and very numerous and closely set.   Each gill-raker has two rows of alternating
diverging flexible filaments, giving a villous appearance to the mouth-cavity.
In this family the gill-rakers on the inner side of each branchial arch are pretty
well developed.   In *Rastrelliger* the gill-rakers are enormously long, so that they
may be seen from the gape of the mouth.   In the Cybiidae the gill-rakers are
shorter than the gill-lamellae, rod-like, and few in number.   Fine but stout tooth-
like processes on the inner side of the gill-rakers are in two or more rows.   In
most species of this family external gill-rakers only are developed.   In *Sarda
chilensis*, however, I found a few, small internal gill-rakers on the first gill-arch.

In the Plecostei the gill-rakers are thin, narrow lamellae with villous teeth
on the inner side.   As the gill-rakers are long, and the gape of the mouth wide,
the former may easily be seen in the latter.   In the species in which the num-
ber of gill-rakers is large, they are well developed in other respects as well, so
that among the Japanese tunnies, *Thunnus orientalis* has the best developed gill-

rakers, and in the genus *Katsuwonus* the gill-rakers are better developed than in the genus *Thunnus*. The inner or axial side of gill-rakers and also calcareous grains on branchial bones are covered with villous teeth. Teeth near the oesophagus are generally a little larger than others. Thus teeth on the lower pharyngeals and the hypobranchial segment of the fourth branchial arch are larger than those on other branchial bones.

In the Katsuwonidae the second, third, and fourth gill-arches carry numerous, thin, elongated gill-rakers, also on the posterior side. In *Katsuwonus*, moreover, the inner margin of the gill-rakers on the anterior margin undulates.

Stomach (figs. 3, 5, 6). In the Scombridae the stomach is a rather thin walled, conical sac, suspended from the roof of the coelomic cavity of the peritoneum, and weak longitudinal folds (about 16 in *Scomber japonicus*) are found near the two orifices, pyloric and cardiac. The cardiac orifice is more or less constricted. The pyloric orifice, situated about midway of the stomach is long and ascending, i. e. turned anteriorly. It opens into the duodenum with a crescent-shaped orifice, as its posterior wall is enormously thickened. In the Cybiidae and Plecostei the stomach is a very long conical sac, the posterior end of which almost reaches the anus. The pylorus, situated quite near the oesophagus, is on the left side of the stomach, and is more or less turned posteriorly. The wall of the stomach is thick, tough, and rich in deep, longitudinal folds, some of which run into the pylorus. The food is chiefly digested in the sac-portion, where the soft parts are almost entirely dissolved and the framework of the hard skeleton is also broken to pieces. The digestive fluid of the stomach is acid in reaction, very powerful, soon dissolving the skin of fish or cuttle-fish, then muscles, and lastly bones. The calcareous portions of the skeleton are dissolved leaving the chondrous substance behind. The gelatinous tissue or tunicine of pteropods, tunicates, &c., jaws, pens, and lenses of cuttle-fish are scarcely changed in the stomach. The stomach of tunnies is very loosely covered outside with the thick peritoneum, and the blood-vessels to the stomach lie under the membrane.

The pylorus is more muscular than the sac-portion, and generally rather short. It runs to the left side of the stomach. In the Scombridae and in the majority of the remaining teleosts the pylorus is ascending. In the Cybiidae the pylorus is slender, variable in length, and is more or less dilated near the distal end, forming a special diverticulum, just before the boundary

with the duodenum. In the Plecostei the pylorus is rounded or more or less ovoidal, being thicker at the proximal portion, and more or less twisted to the right-hand side at the posterior end. The duodenum is separated from the pylorus by a well marked constriction, and suddenly dilates, hence it is more or less sac-shaped. It is thin walled, widest just behind the pylorus, overlapping the latter a little and becoming gradually narrow. It is curved forward, touching the dorsal posterior surface of the liver, and is bent dorsalward, then backward, and lastly bending to the right-hand side, passes to the intestine. In more or less tainted fish the duodenum is the first to dissolve, probably by its own enzymes, i. e. by the action of autolysis. To this portion of the intestine the pyloric cocca and cystic duct open their apertures. The latter duct enters at the anterior side of the duodenum, just near the pylorus, while the former generally open at the posterior side with many apertures, distributed in one or several rows. The pyloric cocca are generally yellowish in colour.

Longitudinal folds of the stomach are mostly about 20 in the Cybiidae, but in the Thunnidae there are usually 30–40, but in the Katsuwonidae they decrease in number again, to about 20 in *Katsuwonus*, 12 in *Euthynnus*, and nearly indistinct in *Auxis*.

Pyloric cocca. In the Scombridae (fig. 1) the pyloric cocca are coarse, numerous, and each coecum communicates directly with the duodenum (*Scomber*), or a few or several cocca coalesce at the root and open by a common orifice (*Rastrelliger*). They are crowded in a long and more or less triangular tract on the posterior or ventral side of the duodenum. Those cocca near the pylorus are long, and their length gradually diminishes in proportion to the distance they are from it. These numerous cocca are connected by loose connective tissue traversing them.

In the Cybiidae (fig. 6) and Plecostei (figs. 3, 5) the pyloric cocca are remarkably well developed and assume a conspicuous size as a mass. The size of each coecum, however, becomes small as the development of the pyloric cocca as an organ advances. In these groups of fish the cocca do not open directly to the duodenum, but to its tubular outgrowths of varying length. These tubules are dendritically branched, have a rather thin but tough wall, and some longitudinal grooves inside. They are more or less capable of distention. Each branch of the pyloric tubules with tufts of cocca is enclosed by **a membrane of**

connective tissue, and the whole mass of the pyloric coeca is again enclosed and connected compactly by a common membrane, the peritoneum. In pyloric tubules we find a viscous, milky fluid; and sometimes half digested particles of food as well, when the stomach is glutted. Mr. Yu Yokoya examined for me the nature of enzymes in the pyloric coeca of *Neothunnus macropterus*, and obtained the result that amylase and protease are present, but he could not detect the presence of lipase. This result confirms other authors' results of investigations, and points out that the chief function of the pyloric coeca is digestive. In this inquiry glandular portion only was used, so that there was little fear of mixing of gastric juice.

In the Cybiidae the number of pyloric tubules is few (2-6), and small one of them is often found on the anterior concave side. The coecal portion is sparingly branched. In the Plecostei the number of pyloric tubules is a little more numerous (5-10), and their short terminal branches carry tufts of simple coeca. Two or three small tubules are found on the concave side of the pylorus in the Katsuwonidae. In the Thunnidae the size of coeca is not uniform, those near the distal end of the longest pyloric tubule being larger than others. The tubule next to the pylorous is longest, and succeeding ones rather suddenly decrease in length. These tubules are generally disposed at the posterior side in a line along the entire length. Their orifices to the duodenum are variable in size and form, being round, oblong, or sometimes slit-like.

Intestine. The duodenum is transferred to the small intestine at the spot where the alimentary canal is bent backward, i. e. at the junction of the ascending and descending parts of the alimentary canal. The length of the small intestine is very variable. It is short and straight in *Grammatorcynus* and Katsuwonidae, and long and more or less folded in the Scombridae, Cybiidae (except *Grammatorcynus*) and Thunnidae. In *Rastrelliger*, some species of *Cybium*, and fishes of the Thunnidae the intestine is comparatively and nearly uniformly slender; but in these cases the intestine is always much elongated. The intestinal tract is a little more slender than the duodenum. In the Katsuwonidae the small intestine is very short, being nearly equal in length with that of the abdominal cavity. But the intestine is often thicker than the rectum, and many weak longitudinal folds are found in it. Sometimes the rectum is thicker than the small intestine. In this family the intestine is nearly equal

in length with the rectum. The rectum is relatively long in *Scomber* too. The boundary between the small intestine and the rectum is indicated by a transverse ridge inside. In the so called scombroid fishes the length of the intestine seems to have but little connection with the nature of food, as voracious fishes of the Cybiidae have often a long intestine, folded several times, and fishes of the Katsuwonidae, which feed on medium sized plankton, have a short, straight intestine. *Rastrelliger* which is a plankton-feeder has a very long intestine, more than 5 times as long as the length of the abdominal cavity. Usually the colour of the undigested ingredients of food differs in different tracts of the intestine. In the
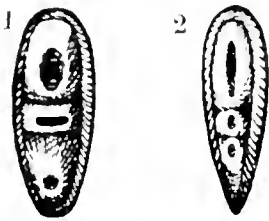
1, *Scomber japonicus*
2, *Neothunnus macropterus*

Fig. M. External aperture of the cloacal cavity (enlarged), showing from above the anal, genital, and urinary openings on the respective papilla.

scombroid fishes the alimentary canal and genital and urinary ducts open to a common depression which is very shallow and communicates to the exterior with an elongated cleft. The anus, genital pore, and urinary pore all open independently on respective papillae. Of these the anus is the largest. The posterior wall of this cloaca-like space is more or less darker in colour than the anterior. When we handle the viscera of a tunny, more or less stale, with naked hands the wet portion becomes itchy, and in certain people the contact occasions small tumors of the skin. This is probably due to the formation of ptomain. In the viscera of a stale fish we often find small crystals on the external surface of the mass of the pyloric coeca.

Liver (figs. 2, 3, 5, 6). The liver is a large brownish organ, generally divided into three lobes, and situated just behind the diaphragm, and covers the anterior and ventral part of the stomach. In the Scombridae the liver differs remarkably in form from the other allied fishes. It is a small, undivided, more or less triangularly pyramidal organ, with three trenchant edges. It is situated at the left, anterior corner of the abdominal cavity. The right hepatic vein is found at the attenuated margin of the right, anterior corner. The middle and right lobes are scarcely developed. In the Cybiidae we find three lobes of the liver, but their respective size and form are variable. Generally the right lobe which is scarcely developed in the Scombridae, is best developed, but the left and middle lobes are poorly developed. In *Gymnosarda*, however, the left lobe is best developed.
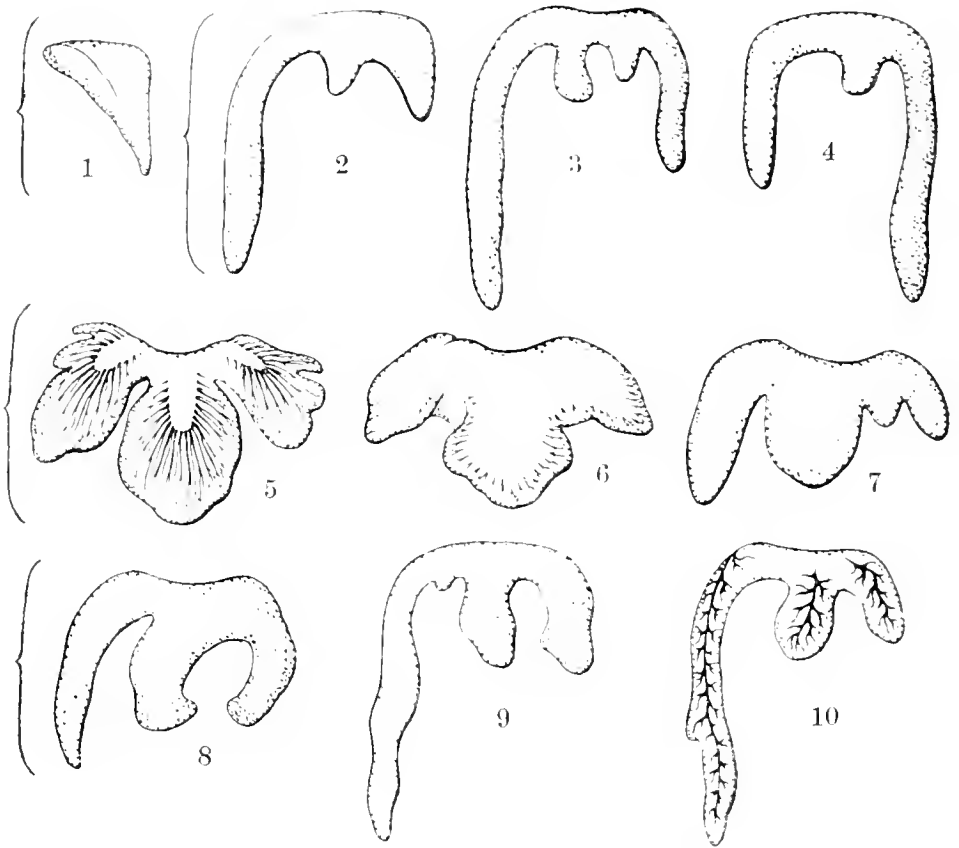
Fig. N. External view of the liver. 1, *Scomber japonicus* ; 2, *Cybium niphonium* ; 3, *Sarda orientalis* ; 4, *Gymnosarda nuda* ; 5, *Thunnus orientalis* ; 6, *Parathunnus mebachi* ; 7, *Neothunnus macropterus* ; 8, *Katsuwonus pelamis* ; 9, *Euthynnus yaito* ; 10, *Auxis maru*.

In the Cybiidae as well as in Scombridae the surface and the outline of the liver are smooth. In the Thunnidae the three lobes of the liver are subequal, but in the Katsuwonidae the lobes of the liver are unequal in size, the right lobe being best developed, and the left lobe is often not well defined. In *Thunnus* (fig. 3) the external surface of the liver is marked with fine venules running very close together, and at the anterior middle portion of the liver, near the spots of emergence of hepatic veins, the liver is very thin, being composed of hepatic venules only. Moreover the liver is divided into many irregular lobules at the margin as well as at the internal or axial side, where

large masses of rete mirabilis of blood-vessels are found. In *Parathunnus* the external surface of the liver has a few short venules near the posterior margin; but in *Neothunnus* no venules are found at the external surface. In these two genera the lobes of the liver are not deeply cut, and in the latter genus the right lobe is a little longer than the other lobes. In *Euthynnus* and *Auxis* (fig. 2) the right lobe of the liver is enormously elongated, almost reaching the anus, while the left lobe is often inconspicuous, being not separate' a distinct indentation from the middle lobe. In *Auxis* moreover dark and thick dendritic figures of the hepatic vein are clearly discernible on the external surface of the liver.

The gall-bladder (figs. 1–3, 5, 6) is an enormously elongated sac, running along the intestine, on the inner side of the right lobe of the liver. The bladder becomes narrow at the anterior part and passes gradually to the cystic duct which is bent backward along the inner side of the middle lobe of the liver, and opens to the duodenum with a narrow duct, ductus choledochus. To the cystic duct three or more hepatic ducts open. These are more or less dendritically branched in the liver. In the Scombridae the gall-bladder is elongated and receives some slender ducts (3 in *Scomber japonicus*). In the Katsuwonidae the hepatic duct in the right lobe of the liver is very long, running the whole length of the lobe. The gall-bladder is greenish in colour, but it is sometimes purplish in a stale fish.

The spleen (figs. 1–3, 5, 6) is a compact, elongated body, more or less compressed, and dark red or brownish in colour. It generally lies close to the junction between the duodenum and the small intestine. It is rather small in the Scombridae and Cybiidae, but in the Thunnidae it is very well developed and is attached to the anterior part of the fold of the small intestine, occupying the space enclosed by the duodenum, and the intestinal tract to the second bend. In the Katsuwonidae the spleen is again small and lies exterior to the intestine. In the genus *Sarda* the spleen is much separated from the liver.

RESPIRATORY SYSTEM.

In the so-called scombroid fishes the gill-openings are very wide, extending from the origin of the chin to the posterior ventral margin of the cranium, and the branchiostegal membranes not being united at the anterior end, remain

free from the isthmus. In the Scombridae we find a slight depression at the posterior, dorsal margin of the gill-opening, just anterior to the origin of the pectoral. This depression together with the soft flappy portion of the opercle above it, make easy the escape of foul water from the gill-chamber. In *Rastrelliger*, moreover, a slight depression or groove is found on the hind ventral margin of the gill-opening, or at the lower, anterior margin of the shoulder girdle. Such structures of the gill-opening as the flappy portion of the opercle opposite to the slight depression of the gill-opening, and another depression on the posterior ventral margin are often found in fishes of the Carangidae as well, and we see that there is some relation between these two families.

The branchiostegals are slender, seven or eight in number, and the membranes connecting them are rather wide and extensive. In the Scombridae the branchiostegals are dissimilar in breadth and form, posterior ones becoming broader and much more curved or bent.

In the Cybiidae the branchiostegals are slender, and the membrane connecting them is extensile. In the Plecostei the posterior branchiostegals are more or less broad, and the free margin of the membrane is much thickened, hence tough from the development of connective tissue. The membrane is nonextensile and remains fastened to the inner side of the opercle, a little removed from its margin, like an inner rim of a lid to a base.

The pseudobranchiae are equally well developed in the Scombridae, Cybiidae, and Plecostei.

The branchial lamellae are very thin, and closely set, nearly equally in all scombroid fishes; but their length and breadth vary greatly in different families. Their length is proportional to the breadth of the opercle. In the Scombridae the gill-lamellae are short and narrow, about half the length of the upper arm of the first gill-arch. In the Cybiidae they are a little longer than half the length of the upper arm of the first gill-arch, and in the Plecostei they are equal in length with the latter. In the Plecostei each branchial filament is strengthened on the proximal, axial side of each gill-arch with many minute transverse rods.

In *Acanthocybium* the branchial lamellae anastomose with each other as in the Xiphiidae, but in the former the anastomosis is limited to the proximal portion of the lamellae, not over the whole extent of the gills as in the latter.

VASCULAR SYSTEM.

In the vascular system too, we find many very important points of difference among the scombroid fishes. Especially the order Plecostei presents many characteristic features, remarkably different from all the other fishes. The chief features of difference are the greater quantity of blood, greater number of blood-vessels, and larger heart. The most noteworthy difference is the development of the cutaneous vascular system, not found in the Teleostei, and peculiar vascular plexus in the lateral muscle, and enormously developed vascular plexus under the liver, or in the haemal canal. Therefore we distinguish three different systems of blood-circulation in the Plecostei, namely vertebral, visceral, and cutaneous. These three systems have respectively a peculiar feature in the Plecostei; but the peculiarity of the vertebral system is alternative with that of the visceral. The cutaneous system is very conspicuous and quite characteristic to the Plecostei, and has a correlation with the presence of the dark red portion of the lateral muscle, round the vertebral column from the development of sheet-like vascular plexus. It is very remarkable that such a conspicuous and peculiar system of circulation remained almost unknown to science. Though the keen eyes of CUVIER (12) discovered it in the common tunny of Europe, he did not put much weight on it, so that he described it rather in passing in the following lines :—

> "Lorsqu'on a levé la peau du thon, on trouve sous la ligne laterale un grand vaisseau, qui donne de sa face externe, en dessus et en dessous, beaucoup de branches dans les muscles voisins. Sa face interne est criblée d'un nombre infini d'orifices d'autres branches, qui vont se perdre sur une membrane glanduleuse épaisse ".

After CUVIER no one has studied nor even mentioned the peculiar blood-vessels. In 1836, ESCHRICHT and MÜLLER (19) published an interesting paper on the peculiar plexus of blood-vessels among the viscera of the common European tunny. In that paper they give a figure, showing the origin of the cutaneous arteries (Taf. III, fig. 3); but identified them with prejudice as the axial arteries, and did not trace further. In 1915 I published a paper on the peculiar circulatory system (44) in the "Suisan Gakkwai Hō" (Proceedings of the Scientific Fishery Association) Vol. I, and in 1918 another paper in the
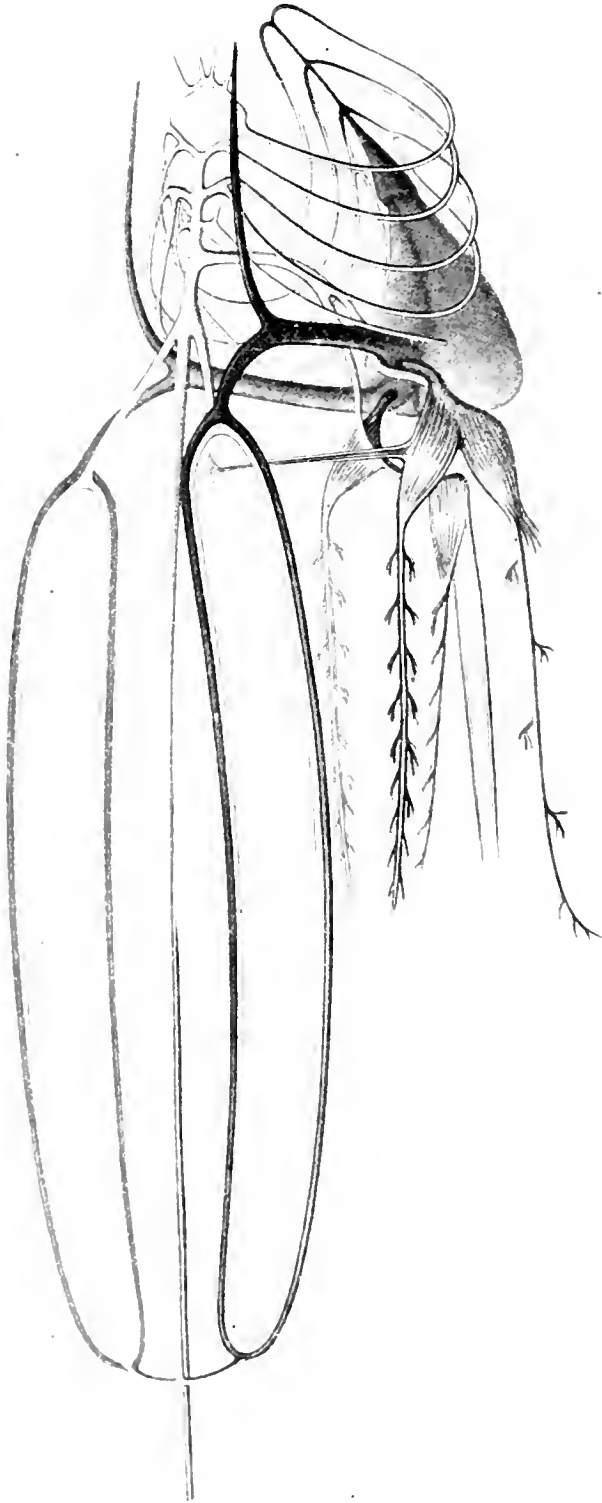
Fig. O. Diagram showing the vascular system of *Thynnus orientalis*.

same journal, Vol II (46).

Besides the peculiar cutaneous system and vascular plexuses on the inner side of the liver described by ESCHRICHT and MÜLLER there is another peculiar plexus in the haemal canal of the vertebral column in *Neothunnus* and Katsuwonidae. In these fishes the vascular plexuses on the inner side of the liver and fine hepatic veins on the outer side of the liver are wanting. Therefore these hepatic plexuses seem to be the alternative of the plexuses in the haemal canal. Both the hepatic plexuses and the plexuses in the haemal canal consist of blood-vessels entirely filled with blood-corpuscles.

In the Plecostei the caudal peduncle is very slender and full of strong tendons, thus there is little space for the sure circulation of blood, and here blood-vessels find a safe passage in the substance of the vertebrae themselves.

The higher temperature of the body than the surrounding water, and consequently great activity of fishes of the Plecostei is undoubtedly due to the peculiar circulatory systems above described.

Venous system. In the Scombridae (fig. 1) the chief vertebral venous system consists of the jugular veins, Cuvierian ducts, posterior cardinal vein, lateral vein, and segmental veins. The visceral system consists of the hepatic veins, hepatic portal veins, and the genital veins from the gonads. The genital veins unite with the posterior cardinal vein separately. The posterior cardinal vein lies below the dorsal aorta and communicates with the Cuvierian duct of the right side. The segmental veins carry venous blood along the neural and haemal processes and intermuscular bones, generally in every other myotome, alternating with segmental arteries. The venous blood from the surface of the body is collected in these segmental veins, but chiefly in those running to the inner surface of the wedge-shaped superficial reddish muscle and then along intermuscular bones. These segmental veins are short and small. The venous blood in the lateral wall of the abdominal cavity is chiefly collected in the segmental veins along the peritoneum and pour to the posterior cardinal vein at the root of the pleural ribs, and partly to the lateral veins running along the ventral median line, collecting some inferior segmental veins in the antero-inferior part of the lateral body wall. The Cuvierian ducts are large vertical ducts, running along the sides of the oesophagus, behind the pericardo-peritoneal septum and join the sinus venosus.

The venous system of the Cybiidae (fig. 6) is nearly similar to that of the Scombridae ; but differs in the development of the renal portal system in the precaudal region, where some segmental veins running along neural processes and intermuscular bones are minutely divided in the kidneys. Nearly at the posterior end of the precaudal region the cardinal vein leaves the haemal canal and runs obliquely downward to clear some preceeding haemal arches and short haemal spines and passes through the kidney, receiving numerous venules there and taking a more or less ascending course rejoins the dorsal aorta in the haemal canal. The segmental vein is not found in every segment, but almost in every other segment, alternating with the segmental artery as in the Scombridae.

In the Plecostei the venous system differs greatly from that of the Teleostei, as stated above, moreover there is a great variety in the system in different forms of the order. In the genus *Thunnus*, the most primitive type of the Plecostei, the cutaneous system is best developed, and the vertebral system is abortive, the posterior cardinal vein being wanting. A short, slender caudal vein is found in the place of the posterior cardinal vein. The caudal vein joins at the middle part to the transverse commissure of the cutaneous veins and thus communicates indirectly with the Cuverian ducts. A pair of cutaneous veins, are found on each side of the body, on the epaxial and hypaxial sides of the lateral median line. These two veins run almost parallel, and quite near each other. They run deep into the myotome of the fourth vertebra, at the hind margin of the myotome, and unite a little below the surface of the body. The confluent vessel runs obliquely anteriorly, passes under the proximal slender part of the third rib, and joins the Cuvierian duct of the respective side, after collecting many renal venules. The right and left cutaneous veins are united by a transverse commissure in the caudal portion. This transverse commissure of the cutaneous vein is found in all the forms of the Thunnidae. Segmental veins, both cutaneous and the vertebral, are found in every myotome.

In *Parathunnus* (fig. 4) the cutaneous veins of both sides pass through the myotome of the sixth vertebra, and each uniting to a large vein running below the fifth rib, pour into a transvers canal behind the pharyngeal muscles. The transvers canal joins the right Cuvierian duct after uniting with a short renal vein. The caudal vein is very slender as in the genus *Thunnus*, and
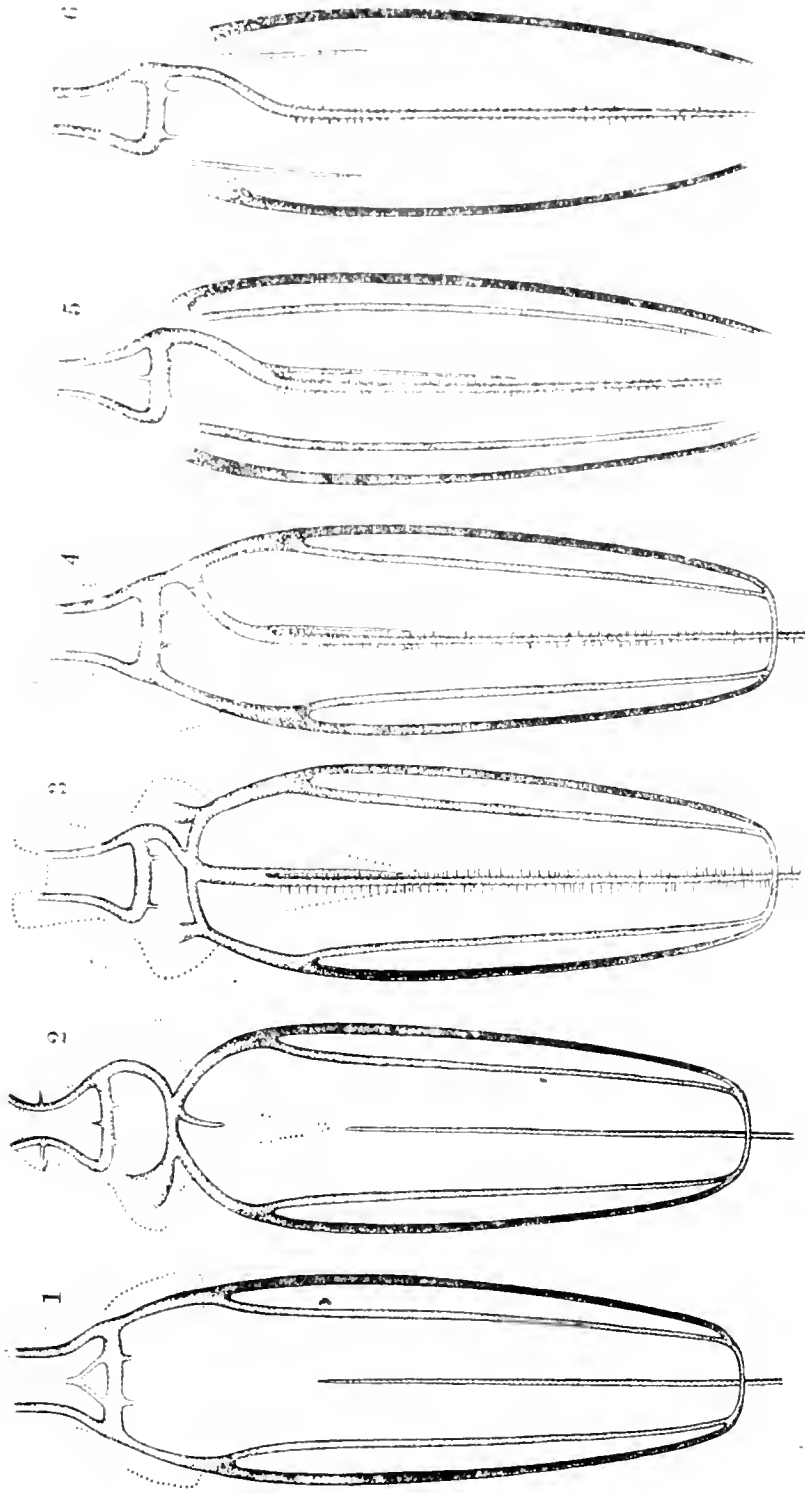
Fig. P. Diagram showing the vertebral and cutaneous venous systems of Pleostean fishes. 1, *Thunnus orientalis*; 2, *Parathunnus mebachi*; 3, 4, *Neothunnus macropterus*; 5, *Katsuwonus pelamis*; 6, *Euthynnus* and *Auxis*. The dotted line shows the outline of the renal organ.

does not unite with the Cuvierian duct directly. In this genus most of the segmental veins running along the haemal spines in the precaudal region and also in the anterior part of the caudal region are divided into many venules near the vertebral column, so that their blood does not return directly to the heart, but seems to be collected to venules above the vertebral column and in the dark red portion of the lateral muscle. This is very remarkable. The segmental veins in the caudal region unite to a slender caudal vein.

In *Neothunnus* the posterior cardinal vein is very conspicuous, and gives off a peculiar plexus in the haemal canal, and at last joins the right Cuvierian duct. The cutaneous veins are united by an anterier transverse commissure as in *Parathunnus*, or sometimes each of them pour directly into the Cuvierian duct of the respective side as in *Thunnus*. A short slender renal vein runs under the posterial cardinal vein and is united to it.

In the Katsuwonidae the vertebral venous system consists of the posterior cardinal vein, jugular veins, Cuvierian ducts, lateral veins, cutaneous veins, segmental veins, and subspinal plexus. The posterior cardinal vein is connected with a remarkably well developed plexus of venules in the haemal canal and joins the right Cuvierian duct as in the genus *Neothunnus*. The cutaneous veins do not join the Cuvierian duct directly, nor are they united by a transverse vessel in the thoracic region to the posterior cardinal vein, but are divided to renal portals. Thus these cutaneous veins differ from the similar veins of the Thunnidae. Moreover the lower cutaneous vein of this family is not homologous to the lower branch of the cutaneous vein of the Thunnidae. The epaxial and hypaxial veins originate in different myotomes and they do not form a loop at the caudal region, nor are they connected by a transverse commissure. In *Katsuwonus* the epaxial and hypaxial cutaneous veins are nearly equal in size and length, and though they are not straight they are nearly equally distant from the lateral median line of the body. These veins run anteriorly and to a deeper part of the body, passing through the myotome of the fifth vertebra. The epaxial vein passes below the first rib, while the lower passes above it. These two veins receive blood respectively from the sheets of vascular plexus on the dorsal and ventral sides of the dark red portion of the lateral muscle. In the other genera, *Euthynnus* and *Auxis*, the epaxial cutaneous vein is very thick and runs close and parallel to the

lateral median line of the body, running to the deeper part of the body between the myotomes of the fourth and fifth vertebrae. The chief cutaneous segmental veins are united to the epaxial cutaneous vein, and sheets of vascular plexus surrounding the dark red portion of the lateral muscle are connected with the vein. The hypaxial cutaneous vein is remarkably short, slender, and zigzag in its course, disappearing from the surface of the body just behind the postclavicle and before the myotome of the first vertebra. In the Katsuwonidae the hypaxial cutaneous vein always passes before and above the first rib. The posterior cardinal vein leaves the haemal canal from the fourteenth vertebra or a still more backward position. Anterior to that point the posterior cardinal vein is more or less separated from the dorsal aorta, receiving several short but comparatively large veins at both sides of the dorsal aorta, and these veins are formed from parallel venules of the vascular plexus in the haemal canal or "kurochiai" in Japanese. At the same point an inferior posterior branch joins the posterior cardinal vein. The branch is a slender renal vein as in *Neothunnus*. The cardinal vein and the dorsal aorta too are situated close to the lower side of the haemal canal, sending a thick rod of vascular plexus above, which fills up the broad canal. The kurochiai appears from the segment of the fifth vertebra in *Katsuwonus*, from that of the sixth vertebra in *Euthynnus yaito*, from that of the ninth in *Neothunnus*, and tenth or twelfth in *Auxis*. In the latter genus the epaxial cutaneous vein passes between the two accessory cones of the lateral muscle (fig. 2).

The visceral venous system of the Pleeostei consists of some hepatic portal veins, hepatic veins, and genital veins. The chief difference from the Cybiidae and Scombridae lies in the genital veins, which directly join the Cuvierian ducts. In the Thunnidae the hepatic portal veins are more or less divided into plexuses or parallel venules before entering the liver. The plexus is most remarkably developed in *Thunnus*. In this genus the venules are interlaced with arterioles of the coeliac artery. Each plexus is as large as a fist, and is more or less conical. In another genus, *Parathunnus*, only venules are found in the plexus, consequently the plexus is thin, elongated, and in the genus *Neothunnus* the plexus is not found at all, but instead of a single trunk, the hepatic portal veins are composed of several parallel venules. Concomitantly with the development of the peculiar plexus on the internal side of the liver, the

hepatic veins are divided very finely and run quite near the external surface of the liver. In *Parathunnus* venules of the hepatic veins on the external surface of the liver are rather short and sparce, while in *Neothunnus* venules of the hepatic veins are few, large and are not found at the external surface of the liver. In immature forms of our common tunny venules on the surface of the liver are short, remarkably shorter than in the adult. In the Katsuwonidae neither the plexus nor the parallel venules among the viscera nor those on the external surface of the liver are found. In *Auxis*, however, black dendritic figures of the hepatic veins are noteworthy on the external surface of the liver. In *Euthynnus* and *Auxis* the right lobe of the liver is elongated, and hepatic portal veins from the pyloric cocca run in many transverse canals to the lobe.

Heart. The heart lies just before the pericardo-peritoneal septum, in a more or less conical space, enclosed and protected by the lower pharyngeals, clavicles, and pelvic girdle. The organ consists of a sinus venosus, auricle, ventricle, and bulbus arteriosus. The sinus venosus is thin-walled and spacious, formed by the union of the Cuvierian ducts below the oesophagus. The sinous communicates with the auricle by a round opening. The auricle is a more or less flattened sac with a triangular outline, covering the dorsal anterior face of the ventricle. The inner side of its wall is reticulated with muscle bundles. The ventricle is firm, thick walled, more or less tetrahedral in shape, with an anterior vertex, ventral edge, and posterior base. In the anterior dorsal face the ventricle is connected with the preceding chambers. Thus here the course of blood-circulation is changed. The posterior face or the base is flat or rather a little concave. The bulbus arteriosus is a laterally compressed sac, ovoidal in form, with a well developed muscular wall. The sinu-ventricular orifice is elliptical with two large pocket-shaped valves, while the auriculi-ventricular orifice is roundish, guarded with four hood-like valves. The size of the heart is remarkably large in the Plecostei as it propels more blood than in the Teleostei. The form of the heart is different in the Plecostei, the base of the ventricle is nearly vertical in the order, while in the Scombridae and Cybiidae it is oblique.

Arterial system. The bulbus arteriosus gradually passes to the short ventral aorta which gives off four pairs of afferent branchial arteries. The aeriated blood in the gill-arches is mostly carried dorsalwards to the efferent
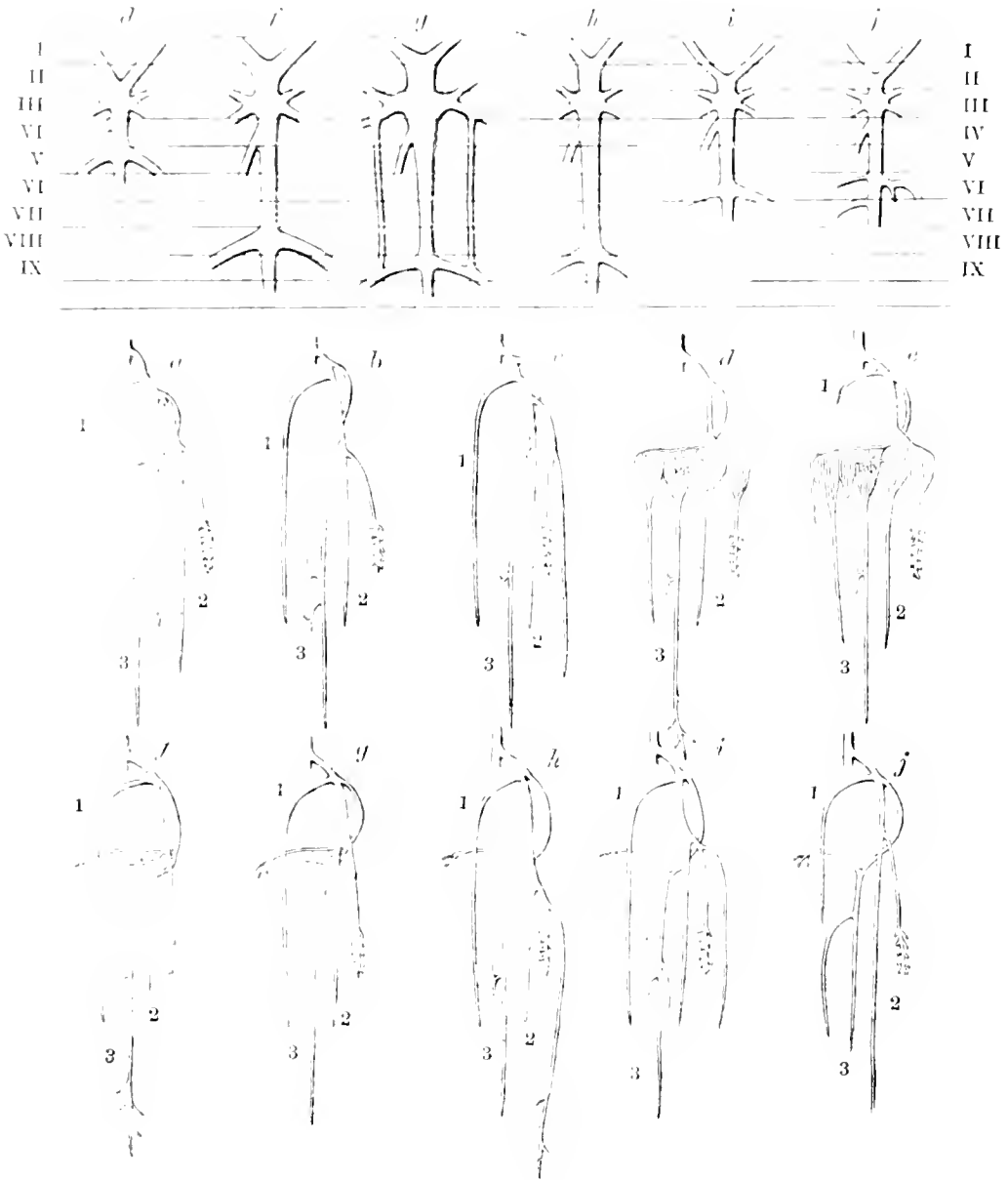
Fig. Q. Diagrams showing the arterial system of the scombroid fishes.

The upper row represents the anterior part of the visceral arterial system, showing the origin of efferent branchial arteries, coeliaco-mesenteric artery, and cutaneous arteries. The Roman numerals denote the cardinal number of vertebrae. The other rows represent the visceral arterial system. *a*, *Scomber japonicus*; *b*, *Cybium niphonium*; *c*, *Sarda orientalis*; *d*, *Thunnus germo*; *e*, *Thunnus orientalis*; *f*, *Parathunnus mebachi*; *g*, *Neothunnus macropterus*; *h*, *Neothunnus rarus*; *i*, *Katsuwonus pelamis*; *j*, *Euthynnus yaito*.

branchial arteries, but a very small portion is sent ventralwards beneath the ventral aorta to form the hypobranchial artery, unappropriately named, which nourishes the heart, ventral fins, and the ventral carinales. In the Katsuwonidae this artery is divided into paired branches behind the ventral fins. A slender artery runs backwards just above the ventral aorta to nourish the heart. The artery is formed by the union of branches of downward efferent branchial arteries in the third gill-arches. A part of the blood in the efferent branchial arteries is conveyed anteriorly by the carotid arteries to the cephalic region, but the greater part of the blood is carried backwards by the dorsal aorta.

To the vertebral system arising from the dorsal aorta belong the renal arteries, subclavian, and in the case of the Plecostei, the cutaneous arteries. The subclavian arteries arise near the the root of the coeliaco-mesenteric artery in front of the pharyngeal muscles. They are short, and are soon divided into two branches, anterior and posterior. The posterior branch running obliquely backward becomes the subclavian or brachial artery for the pectoral fin. The artery is divided again into two or more, the exterior one of which goes to the extensor, the interior one to the retractor muscle of the pectoral fin. The segmental arteries are given off along the intermuscular bones, and also along neural and haemal spines. In the Scombridae and Cybiidae these segmental arteries are generally found in every other segment of the body. In the Plecostei, however, they are generally found in every segment. In the Cybiidae nearly all the precaudal hypaxial branches of the dorsal aorta give off short, dendritic renal arteries (fig. 6). In the Plecostei (figs. 4, 5) only horizontal segmental arteries are found in pairs in almost every segment of the body, and nourish the dark red portion of the lateral muscle, lying above the median horizontal network of the oblique tendons. Generally speaking the cutaneous arteries together with the median horizontal segmental arteries are the source of activity of plecostean fishes. In the Scombridae and Cybiidae these arteries are generally found in every other segment, but in the Plecostei they are found in every segment.

The cutaneous arterial system consists of one or two large trunks running near the lateral median line of the body, originating in the pectoral region, behind the pharyngeal muscle from the dorsal aorta. These arteries are nearly equally as large as the dorsal aorta itself. In *Thunnus* they originate in

the segment of the fifth vertebra, in *Parathunnus* and *Neothunnus* in the segment of the eighth or ninth vertebra. ESCHRICHT observed that the dorsal aorta becomes abruptly slender after the ramification of these cutaneous arteries, in the following words :— " Nach dem Abgang der *arteriæ axillares* wird die Aorta plötzlich mehr als um die Hälfte dünner im Durchmesser ".

In the Thunnidae the cutaneous artery runs obliquely backward and dorsalward, passing behind the third (*Thunnus*) or fifth rib (*Parathunnus* and *Neothunnus*), and reaches the surface of the body before the intermuscular bone, attached above the root of the respective rib. Before reaching the surface of the body each artery is split into two equal branches, running dorsal and ventral to the lateral median line, nearly parallel to each other (fig. 3). They are united again in the caudal portion by a transverse commissure, and the commissure is again united to the dorsal aorta by a pair of horizontal segmental arteries (fig. 4). Each branch of the cutaneous arteries gives off, at the surface of the body, segmental arteries obliquely backwards along the borders of myotomes for some distance and then bends forwards. The dorsal branch sends dorsal segmental arteries only, and the ventral branch ventral segmental arteries only. These cutaneous segmental arteries send arterioles axially, along myocommata or straightly inward (fig. 3). Both dorsal and ventral cutaneous arteries, moreover, send one or two rows of very numerous parallel arterioles, quite close to each other. These arterioles run obliquely inward, along the boundary between the red and dark red portions of the lateral muscle. They are soon divided into several smaller canals and always run in association with similar venules making a membranous sheet investing and nourishing the dark red portion of the lateral muscle. The arterioles in the vascular sheet gradually unite again reduced in number at about midway between the surface and the axis of the body, and vanish in capillaries, so that the dark red portion of the lateral muscle is not entirely covered with fine bloodvessels and capillaries near the axial part. The vascular sheet is thick near the surface of the body, becoming gradually thin as it approaches the axis of the body. In the Plecostei, except *Euthynnus*, the cutaneous arteries always run on the axial and inner side of the accompanying veins. Generally the axial margin of the cutaneous vein partly covers or is at least apposed to the abaxial margin of the accompanying cutaneous artery ; but in

the blue-finned tuna from San Pedro, Cal., I found the axial margin of the
cutaneous vein partly covered by the abaxial margin of the accompanying
artery. In *Euthynnus* (all known species inclusive), however, the cutaneous
artery lies on the abaxial side of the accompanying vein, and the axial margin
of the cutaneous artery is partly covered by the abaxial margin of the
accompanying vein (fig. 26). The distribution of smaller canals on the wall
of the cutaneous arteries is variable in different species, and so far as I have
examined, there are no two Japanese species of tunnies which have the arterioles
distributed in the same way (figs. 20–24).

In *Thunnus germo* arterioles are distributed on the external axial side of
the artery in two or more rows, and they run axially. In *Thunnus orientalis*
arterioles are found on the internal side in one row, in *Parathunnus mebachi*
in two rows, internal and external, in *Neothunnus macropterus* in one row or
two indistinctly alternate rows on the side near the lateral median line of the
body, and in *Neothunnus rarus* in one or two alternate rows at the middle of
the abaxial side. In the Katsuwonidae, the cutaneous artery of the epaxial
side would be homologous to both the epaxial and hypaxial branches of the
cutaneous artery of the Thunnidae. The hypaxial cutaneous artery of the
Katsuwonidae is remarkably short and slender, it generally originates in front
of the epaxial artery, and takes a forward direction, and after passing through
the kidney turns backward, it is situated in a more ventral position than the
hypaxial branch of the cutaneous artery of the Thunnidae. In *Katsuwonus* the
epaxial and hypaxial arteries are nearly equal and originate from a common
lateral branch of the dorsal aorta, in the hind part of the segment of the sixth
vertebra, just behind the pharyngeal muscle. The common lateral branch of
the dorsal aorta is very short, horizontal. It is divided in the kidney into
two canals or rather it is united to a gently curved canal, two limbs of
which are turned backward. The epaxial limb passes beneath the first rib
and then between the intermuscular bones of the second and third vertebrae,
while the hypaxial limb passes over the first rib. In *Katsuwonus* the cutaneous
artery is obviously narrower in calibre than the dorsal aorta, and the epaxial
and hypaxial branches are much more separated from the lateral median line
than in tunnies. The arterioles from these branches are given off at the surface
of the body, between myotomes on both sides of each branch, dorsal and

ventral. Those numerous arterioles nourishing the dark red portion of the lateral muscle run axially. In *Euthynnus* and *Auxis* there are two pairs of cutaneous arteries originating from two different points. The anterior pair is smaller, homologous to the hypaxial limb of the cutaneous artery of *Katsuwonus*, and is given off from the body segment of the sixth vertebra. The artery takes a more or less forward direction, passes through the kidney and then turns backwards. The artery has no relation with the dark red muscle. The posterior pair is very thick, nearly as thick as the dorsal aorta or a little thicker than it, probably homologous to the whole cutaneous artery of the Thunnidae. The posterior pair of cutaneous arteries takes an obliquely upward and backward direction, and makes its appearance at the surface of the body, between the intermuscular bones of the fourth and fifth vertebrae. The artery runs a little above the lateral median line, and seems to vanish in the caudal part. The cutaneous artery sends off segmental branches to the surface of the body, both dorsal and ventralwards, and axially very numerous arterioles to the dark red portion of the lateral muscle. These arterioles are arranged in two diverging sheets to invest the dark red portion of the lateral muscle. In a rare abnormal case, I found the posterior cutaneous artery joined to the anterior cutaneous artery, but in such cases the abnormality is found in one side of the body only.

In the Plecostei subspinal vascular plexus or the kurochiai, the vascular plexus in the haemal canal, deserve attention. In *Neothunnus* vertical arterioles originate as short parallel numerous vessels from the dorsal aorta in the same way as the accompanying venules originate from the cardinal vein and these together make a black red rod as thick as a thumb. These numerous arterioles unite again to two pairs of segmental arteries in each body-segment, one along the intermuscular bone, the other along the neural spine. In the Katsuwonidae the subspinal vascular plexus does not lie just beneath the vertebral column but is more or less separated from the latter. In *Euthynnus* and *Auxis* (fig. 2) the dorsal aorta is so remarkably separated from the vertebral column that the kurochiai is bent like a bow. In *Auxis* the arterioles are few in number and the subspinal vascular plexus is much degenerated. The oblique segmental arteries from the dorsal aorta nourish the dark red portion of the lateral muscle from the axial side.

The coeliaco-mesenteric artery (fig. Q) is a chief unpaired visceral artery originating just before the right pharyngeal muscle. The artery passes the right side of the muscle and is divided into three branches. I shall distinguish them as the first, second and third branch respectively; numbering from the left dorsal side gradually to the right ventral side. The fate or destination of these branches are very different in different species, especially in the Plecostei. The first branch is short and simple, but the other branches are large and branching. In the Scombridae and Cybiidae the first branch nourishes the oesophagus and the left dorsal side of the stomach. The second branch is divided into two branchlets, one of which nourishes the right dorsal side of the stomach and the air-bladder, when it is present, and the other the spleen and intestine. The third branch the ventral side of the stomach and the pyloric coeca. In *Thunnus* the first branch is abortive, and nourishes the oesophagus only or is entirely absent. The second branch is divided into short parallel numerous arterioles in the right lobe of the liver and then reunited to about three branchlets, one to the air-bladder, another to the right dorsal side of the stomach, and the remaining to the spleen, pyloric coeca, and intestine. The third branch runs along the abaxial side of the liver and is also divided into numerous arterioles in the middle and left lobes of the liver. These arterioles are reunited into principal canals, one nourishing the left dorsal side of the stomach, and the other the ventral side of the stomach, pyloric coeca, etc. In *Thunnus orientalis* the third branch is subdivided into two before splitting into numerous arterioles. In *Parathunnus* the first branch nourishes the oesophagus and the left dorsal side of the stomach as in the Scombridae and Cybiidae. The second branch nourishes the air-bladder, right dorsal side of the stomach, spleen, and intestine; while the third branch is divided into two branchlets, one into the liver the other to the ventral side of the stomach, pyloric coeca, and intestine. In *Neothunnus* nearly the same as in *Parathunnus*, but the artery to the liver is much more degenerated. In *Katsuwonus* the first branch nourishes the oesophagus, left dorsal side of the stomach, but in *Euthynnus* and *Auxis* it is very short, slender, and nourishes the oesophagus only. The second branch nourishes the right dorsal side of the stomach, spleen, and intestine, while the third branch nourishes the liver, ventral side of the stomach, and intestine. In the Katsuwonidae the hepatic artery runs more or less forward near the root.

RENAL ORGANS.

The kidneys are well developed in the Scombridae and Cybiidae. They are paired, very thick at the sides of the pharyngeal muscles, but behind these muscles they are blended together and become gradually narrow towards the caudal portion. In *Sarda orientalis* the kidneys are united before the pharyngeal muscles. The organs reach the otic region of the cranium, then run along the ventral side of the vertebral column, between the base of ribs, and lie above the peritoneal membrane of the air-bladder, when it is present. The organs often reach the anus posteriorly. They never enter the haemal canal. The kidneys are reddish in colour, which become paler in preserved specimens and minute black spots may be seen scattered all over them. These are due to the pigment cells accumulated in glomerules. In the Plecostei the kidneys are generally concentrated in the pectoral region. This is especially the case in primitive forms of the order, for instance, in *Thunnus germo* and *Th. orientalis* the kidneys are more or less ring-shaped, as the organ of one side is connected to the organ of the other side at the anterior and posterior sides of the pharyngeal muscles. In these forms of tunnies a slender kidney-like organ enters the haemal canal and runs more or less posteriorly, just below the vertebral column. The organ is thickened at the root of each haemal arch. In other forms of tunnies the kidneys are elongated backward along the dorsal wall of the abdominal cavity. In the Katsuwonidae the oblong space for the passage of the pharyngeal muscles is divided by a median longitudinal bridge of kidneys. The seemingly renal organs in the haemal canal are detached from the main body in *Katsuwonus*. In *Auxis* the renal organ is not found in the haemal canal. It is not developed in the cephalic region, and its posterior part is divided into two long slender bodies, running on both sides of the posterior cardinal vein.

In the Scombridae the ureters are nearly separate from each other, in the Cybiidae they are separate for the most part, but are united to a short median duct, before opening to the urinary bladder. In the Thunnidae they are united to a long median duct, but they are nearly separate again in the Katsuwonidae. In *Thunnus germo* two ureters meet nearly in a transverse line, perpendicular to the median united duct, and at the middle of the former there is a short

median septum. In *Thunnus orientalis* the two ureters meet in a figure like U, and in the other forms of the Japanese tunnies they meet like the figure V. In *Katsuwonus* the two ureters run quite near by in the posterior slender part of the kidneys, and finally unite to a median canal of some length. In *Euthynnus* and *Auxis* the two ureters are nearly separate.

The urinary bladder is variable in size, form and position. Generally it is small and lies behind the peritoneum, but in *Acanthocybium*, *Neothunnus*, and *Auxis* the bladder is large or much elongated and is found in the abdominal cavity, suspended in the mesentery or between the two genital glands and above the rectum.

REPRODUCTIVE SYSTEM.

In the scombroid fishes the generative organs are paired, large, and elongated sacs on the roof of the abdominal cavity, suspended in a fold of the peritoneum, and extend along almost the whole length of the cavity. The organs on both sides are symmetrical, nearly equal to each other in form and size. In *Auxis* the generative organs, both male and female, extend backwards along the side of the anal fin. This backward extension is not so marked as in the case of the female flatfish, but its cause is the same — the narrowness of the abdominal cavity. In scombroid fishes the genital glands generally seem to ripen in the third year of growth, that is when the fish is two years old.

The testes have trenchant edges, hence more or less lanceolate in cross-section, and when ripe, milky white to light yellowish in colour. The ovaries are fusiform, more or less roundish in cross-section, and yellowish in colour, and greater in volume than the testis. In tunnies the gonads grow very large, attaining several kg. in weight. As the eggs in them are minute as in other fishes, their number is no doubt enormously large.

Scombroid fishes generally spawn in the warm season, and in the open sea. So far as I know, *Scomber japonicus*, *Cybium niphonium*, and *C. koreanum* are the only species which spawn in our bays and inland seas. Spawned eggs and larvae of the plecostean fishes are still unknown.

The generative organs of both sides coalesce near the hind end, and the lumen in them unite to a short and wide duct, which opens as a transverse slit on a papilla, behind the anus.

Biology and Ecology.

HABIT.

The scombroid fishes are said to be pelagic, but only the fishes of the Plecostei are truly pelagic. The mackerels, *Scomber* and *Rastrelliger*, live in littoral waters, and most seerfishes too. The tunnies and bonitos, however, feed, spawn, and grow in the open sea.

Scombroid fishes generally swim to the shallower strata of water at night, and return to the deeper layer in day-time, probably following the movement of the plankton, and also that of those animals which feed on plankton. Thus the twilight is the best time for fishing these fishes.

Scombroid fishes swim near the surface of the sea, in and after the spawning season. These fishes are alert and very difficult to catch. They approach the shore in warm seasons, and retire to deeper layers of water in off-shore grounds in cold seasons. When a southerly wind blows, the common tunny comes near the surface of the sea, and also approaches the shore. Until recently, no drifters for the tunny were found out on the sea, when other winds prevailed. Lightning and the sound of thunder are said to frighten tunnies and bonitos, driving them into deeper strata of the water.

Tunnies are often said to resort to the neighborhood of deep rocky banks, rising to ca 200 m below the surface. Especially *Parathunnus mebachi* swim in rather deep layers of water, about one hundred metres below the surface. *Thunnus germo* is said to descend to a depth of ca 80 m, while the other tunnies can descend to a depth of ca 50 m. In summer, schools of *Thunnus orientalis* and *Neothunnus macropterus* sometimes swim with the tips of the dorsal fins and the anal out of the water. Bonitos swim quite near the surface of the sea, and seldom descend below forty metres.

Scombroid fishes often leap out of the water, or show the posterior portion of their body, especially when they are feeding. *Parathunnus mebachi* is said to have a peculiar habit of leaping out of the water at day-break.

Scombroid fishes very soon succumb after a violent convulsion, when caught and taken out of the water. They are very difficult to keep alive, except the common mackerel, as they dart against the fence, when confined in a narrow space, and they can not exist in water of low salinity. Tunnies desert

littoral grounds after a heavy rain, and approach the coast in summer, after a long draught. In the Bay of Yenoura, at the foot of Mount Fuji, tunnies are sometimes kept alive, surrounded by a wall of strong netting near the shore.

Pelagic scombroid fishes often crowd under drift wood or algae, or follow whales or vessels. *Acanthocybium solanderi* is attracted to bundles of wood moored at the surface of the sea, purposely devised by fishermen.

Fishes of the Cybiidae are voracious and audacious. They strive to get out of a pound-net, pushing their head through the meshes at the bottom at night, though in the day-time they are afraid to pass through meshes.

Plecostean fishes are especially timid, as was observed by previous writers, and do not dare to pass through the meshes of a net, until they are confined in a narrow space, though the meshes are wide, expanded, and large enough to be passed freely. Neither do they enter a dark cove, nor approach very near a rocky precipitous wall. When some fish are entangled in a net, and are struggling to escape, the remaining fish of the school are scared away. It is, moreover, told that they are terrified and disappear when they see blood. Thus the throwing out of bilge-water, contaminated with blood, is not permitted at the fishing ground, and with the same reason long lines of sharks are considered to be disadvantageous to bonito fishing, as sharks shed blood when hooked.

Generally the male fish come first, in the middle of the fishing season the number of both sexes is nearly equal, and at the end of the season the female fish predominate.

The habits of the scombroid fishes are often influenced by tides. Mackerels often float towards the surface of the sea, shortly after the flood-tide. Some seerfishes are said to be very active in the ebb-tide, and *Gymnosarda nuda* is said to bite hooks well, when there is no tidal current. Some tunnies are said to resort to the shore with the flood-tide.

Bonitos, except *Euthynnus yaito*, are said to be very clever in making a school of small fish very dense, by swimming round the school of the victims, and devouring stray or forlorn individuals gradually. On the contrary, tunnies and seerfishes swim into a school of victims, and disperse them. The feeding of a fish seems not always the same throughout the year. The striped bonito is said to decline to take bait in certain seasons, generally in mid-summer.

FOOD.

Fish belonging to the genus *Rastrelliger* seem to feed exclusively on plankton, chiefly copedpods. *Scomber* is also a plankton-feeder, but its food differs in different seasons and localities. In bays the fish is omnivorous, and feeds near the bottom; but in the open sea it seems to feed near the surface. Fishes of the Cybiidae are voracious, and feed chiefly on surface-swimming and school-making fishes, such as sardines, anchovies, saurels, mackerels, sand-eels, &c.

Tunnies are also voracious, and most of them feed chiefly on plankton in the open sea. So far as I know, *Neothunnus rarus* seems to be the only species which feeds near or in littoral waters, and chiefly on fishes of moderate size. When tunnies devour fish of somewhat large size, they break their vertebral column near the neck or the tail, probably with their strong jaws, most likely to prevent movement of the engulfed fish in the stomach. Once I found a specimen of *Lepidopus*, about two metres in length, in the stomach of a tunny. It was found bent several times in the stomach. A full-grown tunny can swallow bonitos or young tunnies under 40 cm in length. The smallest animal found in the stomach of a full-grown tunny measured about 5 mm. in length. Judging from the position of food in the stomach, we understand or rather imagine that tunnies swallow fish sometimes from the head, and sometimes from the tail. Tunnies feed on living animals, but they are enticed by deceased or preserved baits as well, and even to artificial batis when they are moving in water. The food of bonitos is nearly the same as that of tunnies. However, bonitos can not swallow large animals as tunnies do. Many interesting forms of the plankton and immature fish, etc. may be found in the stomach of tunnies and bonitos. I have obtained two fine specimens of *Mola mola*, very large phyllosoma of *Scyllarus*, immature specimens of free-swimming stages of *Scyllarus* and *Panulirus*, *Onychoteuthis*, a great many specimens of *Watasenia scintillans* from the mouth of Tokyo Bay, several species of *Pteraclis*, *Acanthurus* (immature), *Chaetodon* (immature), *Maurolicus*, *Argyropelecus*, *Holocentrum*, *Ostracion*, *Caesio*, *Exocoetus*, *Sergestes*, *Acanthephyra*, different kinds of Heteropoda and Pteropoda.

Scombroid fishes feed on swimming animals, and do not prey at the bottom, nor at a wall nearly perpendicular. They swallow the food, darting quickly towards it, and swim away more or less downwards, therefore they are forced

to make a large circuit if they intend to take food again near the same spot as before. Generally they hesitate to swallow food, when it is too large for a mouthful. As a rule they pursue food into shallower strata than those they are accustomed to. While feeding, fishes in a school swim in different directions as they like. A fish which has taken plenty of natural food, is easier enticed to baited hooks than one with an empty stomach. This may be explained by the fact that the fish become frenzied from competition when feeding in a school, and bite any object, suspended or moving in the water, but when they are not feeding they are rather shy and suspicious, and thus do not easily bite baited hooks. When tunnies bite baited hooks, they swim downward at once very quickly, about 200 m, more or less obliquely, so that tunnyfishermen are provided with a strong line, longer than 200 m.

DEVELOPMENT AND GROWTH.

The development of mackerels and certain scerfishes can be studied; but that of the plecostean fishes is very difficult to study, as these fishes do not approach the land, at least in the spawning season. I have not yet succeeded in obtaining these fishes with mature reproductive elements. Consequently the larval and postlarval fishes of the Plecostei are still unknown. Two small specimens described and figured by LÜTKEN (53) and identified to be the young of *Thunnus alalonga* are the smallest examples, so far as I know; but most probably they do not belong to the Plecostei, as the foremost spine of the first dorsal is remarkably shorter than succeeding spines. They would most probably be immature forms of the Cybiidae, as the jaws are long and the teeth large. An immature specimen caught in a tow-net during the Challenger Expedition, between the Admiralty Islands and Japan, and described by GÜNTHER (32) is probably a plecostean fish.

In May, immature fishes of *Scomber japonicus* about 45 mm in length are caught together with colourless fries of the sardine, anchovy, etc. near the coast on the Pacific side. These immature fishes have slenderer body, rounded snout, teeth in the lower jaw in two rows, but remarkably few in number. In September they grow to the

Fig. R. *Scomber japonicus.* Nat. size.

length of about 12 cm, in October 15 cm, and when one year old to 18 cm. I am

inclined to believe that the young fish, about 27 cm long are two years old, and young ones about 35 cm are three years old, and sexually mature. Thus the growth of our common mackerel seems to be nearly the same as that of *Scomber scombrus* of the Atlantic. However, this rate of growth is slow compared with that of other scombroid fishes, and needs confirmation.

So far as I know, eggs of the scombroid fishes are pelagic, spherical, and each egg is provided with a pretty large oil-globule. There are very little distinctive characters in eggs of different species. Eggs of *Cybium niphonium* are very large, the largest among the pelagic eggs, found in the Inland Sea in spring.

In 1920 I found a larva of *Cybium niphonium*, 8 mm in length, among a bunch of immature forms of various fishes from the bunt of a seine, hauled to catch the adult of that species, on June 7th, in Kagawa-ken. The larva has a very long snout, powerful jaws with large teeth, preopercle with three spines, very short but broad precaudal portion, pigment spots on the head and along the ventral median line of the caudal portion. An immature fish of 33 mm in length has a larger head and broader body than the adult. The preopercle is

armed with about four spines. The pectoral is small and rounded, and the posterior portion of the second dorsal and anal begin to be separated to finlets. In this specimen the precaudal portion was elongated to a nearly similar length as the caudal. The first dorsal is higher than the second. An immature fish of 100 mm, caught late in July, 1914, has a still broader body than the preceding. The first dorsal is lower than the second dorsal, and the caudal is much

Fig. S. *Cybium niphonium* (immature). 4/3.

Fig. T. *Cybium niphonium* (immature). Nat. size.

developed. The general appearance is quite similar to that of the adult. The colour markings are however wanting. In the immature fish below this size

the outer margin of the first dorsal gradually descends and its spines are 20 or 21 in number instead of 19 in the later stages, due to the depression of posterior spines. In October the immature fish grows to a length of ca 27 cm, and attains all the specific characters of the adult. As the fish grows the spines in the fin become longer, especially at the posterior part. One year old fish is ca 50 cm long and immature, while a two year old fish is about one metre and is mature.

Cybium koreanum spawns in June and its immature fish is about 24 cm. in September. It has a larger head, second dorsal and anal lower than the adult, and a few, scarcely visible markings in a row, just below the lateral line in the precaudal region.

An immature fish of *Cybium commerson*, 13 cm. long, was caught on July 27, 1916 near Keelung, Taiwan. It has a larger head, remarkably broader body, shorter snout, and larger eyes than the adult. The first dorsal is higher and its hind portion remains colourless. About ten oblong markings are found at the back. They scarcely pass down the lateral line. A little larger specimen in the Museum at Taihoku measures 22 cm in length, and has larger eyes. The colour markings are elongated downwards, but they are not continuous, more or less bead-like, and new markings are added between the old.

An immature fish of *Sarda orientalis*, 17 cm in the total length, was caught at the end of April, 1922, in a large dip net, called "bōke-ami," in the Harbour of Kushimoto, Wakayama-ken. The net was used at night under an artificial light to catch fries of the mackerel. The immature fish of *Sarda* has about twelve transverse bands. In each of these bands we find about six
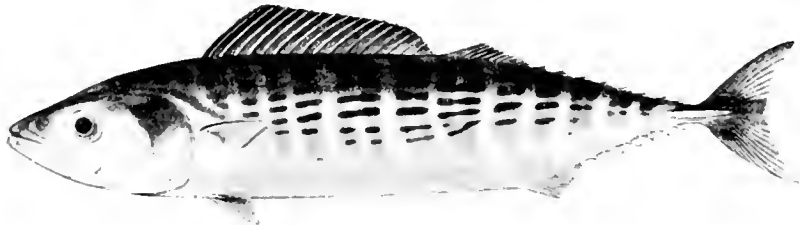
Fig. U. *Sarda orientalis* (immature). 2/3.

longitudinal bands, which ascend more or less backward. Pectorals, second dorsal, and anal are very small. In September, 1900, a little larger immature fish, 23 cm in length, was caught in a ground seine on the east coast of

Aomori-ken. This specimen is nearly the same as the preceding one, but it is a little broader.

An immature fish of *Acanthocybium solandri*, 27 cm. in the total length, was caught off Daisaki, Miye-ken, in September 1917. It has about twenty transverse bands. Those in the precaudal region fade away near the ventral median line, but in the caudal region they are manifest from the back to the ventral median line.

The growth of tunnies seems to be very rapid. The common tunny, *Thunnus orientalis*, most probably reaches maturity in the third year of age. *Thunnus orientalis*, ca 22 cm in the total length, is the smallest specimen I have seen. It has ten to fifteen faint transverse bands which fade toward the ventral median line. These transverse bands are divided into two at the ventral part. Such small individuals are found in August and in September. Some of them grow to a length of 30 cm or more. By next spring they grow to a length of ca 60 cm (fig. 43). When two years old they are about one metre in length and eleven kg. in weight. Three years old fish is considered to weigh about fifteen kg. The growth of *Thunnus germo* and *Neothunnus*
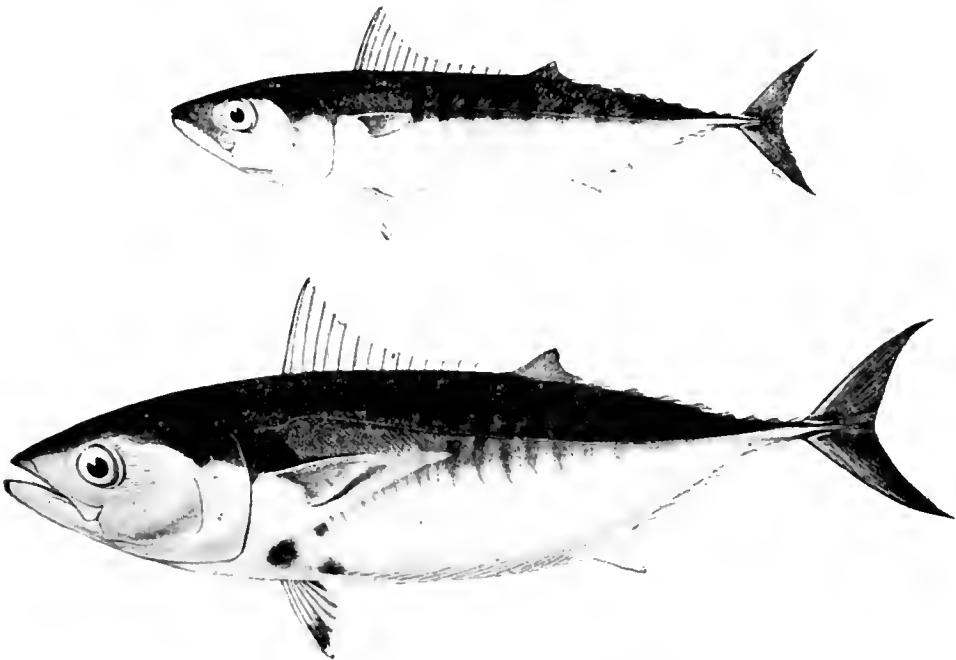
Fig. V. *Euthynnus yaito* (immature). 2/3.

macropterus in the first and second years seems to be nearly the same as that of the common tunny; but in the young form of *Thunnus germo* reticulating longitudinal bands are found, instead of transverse bands.

The smallest specimen of *Katsuwonus pelamis* in my collection is 21 cm. in the total length. It has a slenderer body than the adult, three dark oblique markings at the back of the caudal portion, and one faint longitudinal band under the lateral line. This specimen was caught in August, 1916, at Okinawa-ken, and seems to have been a fish hatched during the same year. The smallest specimens of *Euthynnus yaito* in my possession are 13 cm in the total length. One of them was sent by Mr. GOBEE. It was collected by the SS "Gier" in November, 1907. The other specimen was collected near Keelung, Taiwan, in 1919. They are very slender and have eight or more transverse bands on the side. These bands are nearly vertical and fade toward the ventral median line. When they grow to a total length of 19 cm the body becomes very broad, the thoracic spots appear, the bands gradually disappear from the ventral part, and the dorsal part of the bands becomes oblique.

Mr. S. TOMINAGA sent me several immature specimens of *Auxis maru*, which he obtained from the stomach of striped bonitos, caught off Awakmijima, Okinawa-ken (Ryukyu). They measure 11–17 cm. in length. The largest specimen is nearly the same form as the adult, but the specimens, 11–13 cm in length, are remarkably slender. The skin is more or less damaged by gastric juice, and the markings are not found in these small specimens, but in the largest specimen, there seem to be some transverse bands. They were collected on July 10, 1921.

LOCOMOTION.

About the locomotion of the fishes of the Scombridae and Cybiidae there is nothing new or peculiar. It is quite similar to that of other teleosts. Swift and unceasing locomotion is, however, characteristic of the Plecostei. It is impossible for fishing boats, running about 10 knots an hour, to accompany a school of the striped bonito in progress, so that fishermen throw out live baits to attract and thus to retard or stop the progress of the school. Plecostean fish scarcely bend their body in locomotion, except the caudal peduncle, as will easily be understood from the form and construction of the

vertebral column, it can not be easily bent. The tail-fin is rigid and lunate, its quick and powerful strokes can be understood from the quick and high pitched sound produced by the fish in its death-struggle on the deck of a boat when caught. If a landing hook is driven by mistake into the caudal peduncle of a tunny, we can not hold it, as the hands become paralyzed from the violent convulsion of the muscles. Neither can we hold, even for a few seconds, a landing hook driven accidentally into a tunny swimming away from our boat. Really bonitos and tunnies swim like meteors. The troll-line for tunnies as well as the line attached to a harpoon-head used in tunny-fishing require a reserve of at least 200 m, though the troll-line for a seerfish has a reserve of only 30 m or often none at all.

MIGRATION.

The scombroid fishes, especially the plecosteans are good swimmers, and as they are voracious, they are forced to swim about incessantly in search of food. Like many other fishes, scombroid fishes generally swim in shallower strata of water at night, and seek the deeper strata in day-time. They migrate more or less according to the change of temperature. In the cold season they seek lower latitudes, in summer they go further north; but *Cybium commerson* seems to be exceptional, visiting the western coast of Hondo in the Japan Sea in winter only. The migration of the striped bonito is also remarkable. On the Pacific coast the fish migrate with the warm current and in summer they reach the southeastern coast of Hokkaido and remain there till autumn. In their northerly migration they approach the coast, but in moving south they swim off-shore. In the Japan Sea they take a quite different course, approaching the coast in their southerly migration in the cold season. The migration of *Thunnus orientalis* and *Th. germo* in the Pacific coast is nearly the same as that of the striped bonito. *Thunnus orientalis* in the Japan Sea approaches the coast in going north, in early summer.

Generally speaking of scombroid fishes, large and old are caught at the beginning of the fishing season, while at the end of the season only young and small ones are found.

DISTRIBUTION.

Scombroid fishes are generally widely distributed, and many of them are really cosmopolitan; but some of them are confined to limited districts. For instance *Cybium koreanum* and *Neothunnus rarus* have restricted distribution. Generally speaking the mackerels and seerfishes which have a wider range in vertical distribution have a narrower range in horizontal distribution.

Scomber japonicus is very widely distributed. It is said to occur in the Pacific as well as in the Atlantic. In the Pacific it is found on the Asiatic as well as on the American coasts. However, the fish is not found round the oceanic islands, such as the Ryukyu Islands, Ogasawara Islands, and South Sea Mandates. Adult mackerels migrate in summer to shallow waters, ca 20 m deep in a bay, but retire in autumn to deeper waters of 40–100 m, and in winter to off-shore banks, ca 200 m in depth. Generally mackerels are not found in deeper strata of water than ca 100 m. In waters within the 100 m line of depth, mackerels are found 1–4 m above the bottom. They come near the surface in the evening, and may be attracted to shallow strata within 40 m below the surface.

Rastrelliger is confined to the Ryukyu Islands in our country, but it is widely distributed in the tropical seas.

In the Cybiidae, *Grammatorcynus* is found only in Ryukyu Islands in our country, but is widely distributed in the tropical region of the Indo-Pacific. *Cybium niphonium* is found in the littoral waters of Japan, Korea, and China. *Cybium koreanum* is restricted to the west coast of Korea. It is remarkable that this species ascends the brackish part of rivers. *Cybium commerson* is regularly caught, though in small numbers, near Senzaki, Yamaguchi-ken, in autumn and winter. This species is caught in abundance in Formosa in spring. *Cybium guttatum* is found in our waters only in Formosa. *Cybium chinense* is found in Japan and China, frequently near the Korean Channel; but they are rather rare in other regions. *Acanthyocybium solandri* is a pelagic species, nomadic in habit, and inhabiting warm seas. It is found at the mouth of Tokyo Bay, in the east, and in the south western part of the Japan Sea. *Sarda orientalis* is abundant in Kyushyu, but it may be found in Aomori-ken in the north, both off the Pacific and the Japan Sea coasts. None have been found in Formosan waters. I do not know whether the Indian species of *Sarda* is identical

with our species or not. The Hawaiian species looks quite similar to one species in external characters; but minute examination is necessary for identification.

So far as I know the plecostean fishes are most rich in number of species in our waters. Among our tunnies, *Thunnus orientalis* is rather widely distributed. *Neothunnus rarus* is found only in Kyushyu and the south-western part of the Japan Sea. In the Japan Sea we find only three species of tunny;— *Thunnus orientalis*, *Neothunnus macropterus*, and *Neothunnus rarus*. The latter two species, however, are very few in number, and there is no regular fishing for them. All the species of tunnies found in the Japan Sea live near the surface and approach the coast. The tunnies inhabiting off-shore grounds and descending into rather deep strata of water have not yet been found in the Japan Sea. This is most probably due to the fact that the temperature of the sea is too cold for these species. Bonitos are also found in the Japan Sea; but rather few in number, and *Euthynnus yaito* is very rare.

The scombroid fishes with the air-bladder have generally a wider range of vertical distribution than those without it. The latter group of fish is often restricted to the surface of the water. Or they are near the surface in some seasons, and descend to deeper layers of the sea in other seasons. They can not change their abode suddenly, but when the change is gradual they can endure it. Most scombroid fishes swim in shallow strata of water, but tunnies generally, especially *Parathunnus mebachi*, are found in deeper strata of water than bonitos. Bonitos and voracious species of the Cybiidae frequent the surface of the sea and are readily attracted to artificial baits. These fishes are rarely found in deeper strata than about 80 m.

The scombroid fishes are found in warm seas, the majority of them belonging to the tropical and subtropical regions, and most of them are very widely distributed. They swim very fast in search of prey, and many of them have their own blood-temperature as higher animals. Our common mackerel and the striped bonito are cosmopolitan species. The long-finned tunny (*Thunnus germo*) and *Acanthocybium solandri*, too, seem to be widely distributed, though a critical determination of the species from different parts of the world has not yet been made. The following tables illustrate the distribution of scombroid fishes in our waters and adjacent regions.

	Pacific Ocean										Japan Sea						Yellow Sea		Eastern China Sea			
	South Sea Islands (Japanese Mandates)	Taiwan (Formoso)	Ryukyu Islands	Ogasawara Islands	Kyushu	Inland Sea	Southern Coast of Shikoku	Middle Hondo	North Hondo	Hokkaido	Karafuto	Hokkaido	North Hondo	Middle Hondo	West Hondo	Chosen (Korea)	Chosen	South Manchuria	China	Kyushu	Ryukyu Islands	Taiwan (Form. sea)
Scomber japonicus	×				×	×	×	×	×	×	×	×	×	×	×	×			×	×		×
Rastrelliger chrysozonus	×	×	×																			
Grammatorcynus bilineatus	×	×	×																			
Acanthocybium solandri			×	×	×		×	×														
Cybium commerson								×							×		×					
Cybium niphonium					×	×	×	×	×	×			×	×	×	×			×	×		×
Cybium chinense					×		×	×	×	×			×	×	×	×	×	×		×		
Cybium koreanum																×	×			×		
Cybium guttatum																			×			×
Sarda orientalis			×		×		×	×	×	×				×	×	×						
Gymnosarda nuda				×	×	×	×	×	×	×	×	×	×	×	×	×				×	×	
Thunnus germo		×	×	×	×	×	×	×	×	×		×	×	×	×	×				×	×	
Thunnus orientalis				×	×	×	×	×														
Parathunnus mebachi		×	×	×	×	×	×	×	×	×										×		
Neothunnus macropterus	×		×	×	×		×	×	×	×	×	×	×	×	×					×	×	
Neothunnus rarus					×															×		
Katsuwonus pelamis		×	×	×	×		×	×	×	×										×	×	×
Euthynnus yaito		×	×		×		×	×	×	×										×	×	×
Auxis hira		×	×		×	×	×		×	×	×	×	×	×	×	×			×	×	×	×
Auxis maru			×		×	×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×

Table showing the temperature of water in which
scombroid fishes are found.

	5	10	15	20	25	30
Scomber japonicus						
Cybium niphonium						
Sarda orientalis						
Gymnosarda nuda						
Thunnus germo						
Thunnus orintalis						
Parathunnus mebachi						
Neothunnus macropterus						
Katsuwonus pelamis						
Euthynnus yaito						
Auxis hira						
Auxis maru						
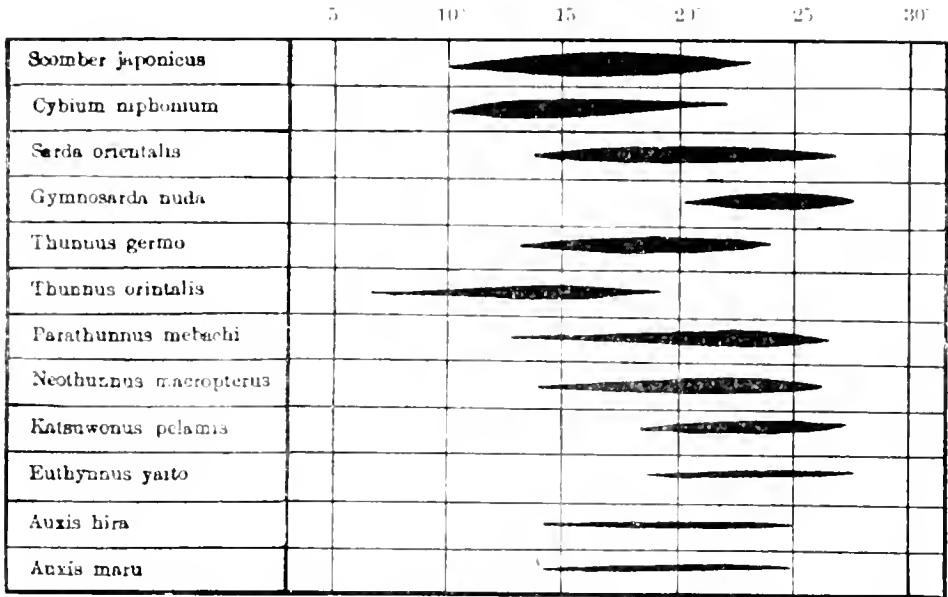
Table showing the vertical distribution of scombroid fishes.

	0	20 m	40 m	60 m	80 m	100 m	120 m
Scomber japonicus							
Cybium niphonium							
Thunnus germo							
Thunnus orientalis							
Parathunnus mebachi							
Neothunnus macropterus							
Katsuwonus pelamis							
Auxis hira							
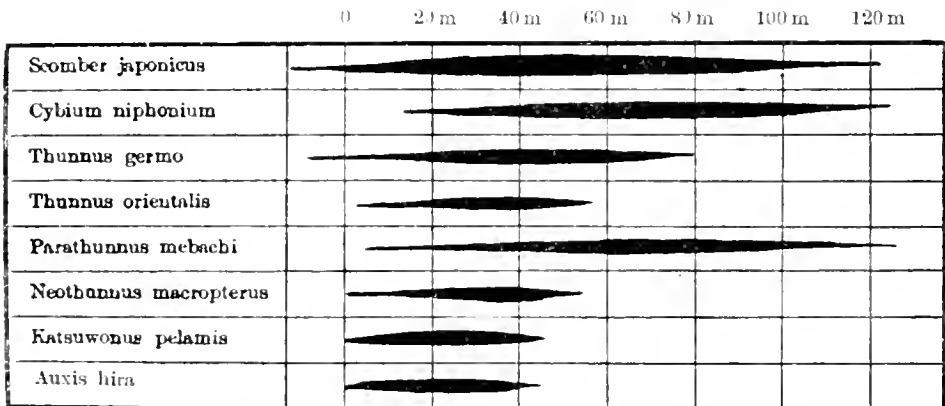
The salinity of the water, most suitable for our scombroid fishes, differs very greatly for different species. Generally speaking fishes of the Scombridae and Cybiidae are adapted to water of lower density, 1.022—1.025, while plecostean fishes prefer water of higher density, 1.025—1.027. *Cybium koreanum* can withstand water of very low density. Of the Katsuwonidae, species of *Auxis* are sometimes found in littoral waters of low density.

ENEMIES AND PARASITES.

The gigantic species of the scombroid fishes have few enemies. Their most dreaded enemies are dolphins, especially the killer. Killers often await the passage of large schools of tunnies in a strait, such as Tsugaru Strait, and attack them furiously. Favourite resorts of killers in the strait are near Cape Ōma and Cape Tappi. Small species and immature forms, however, have many enemies—seals, dolphins, spear-fishes, the sword-fish, sharks, and larger forms of their own or allied species. When we find dolphins in places, where mackerel fishing is actually carried on, the mackerels very soon desert the ground, and do not come back for some days after.

External parasites are mostly copepods and trematods. They are found on the upper surface of the pectoral fin, the inner side of the opercle, gill-lamellae, in the nasal cavity, the mouth cavity, etc. These parasites are, as a rule, not numerous; but sometimes copepods are found in large batches. The *Octocotyle* is a minute parasite found among the gill-lamellae of *Scomber japonicus*, but the *Hexacotyle* is large and is found among the gill-lamellae of *Parathunnus mebachi*. *Tristomum* lives in the nasal cavity of tunnies.

Internal parasites are chiefly trematods and nematods, living in alimentary canal, circulatory system, muscles, tissues of the viscera, etc. Species of *Distoma* use *Acanthocybium*, tunnies, and bonitos as hosts. *Rhynchobothrium* is found in the flesh of *Katsuwonus pelamis* rather abundantly in summer. A species of the Filariadae generally inhabits the superficial dark red muscle of *Parathunnus mebachi*. The parasite changes the colour of the muscle, which becomes more or less yellowish. Once I found a very long nematod in the cutaneous artery of *Euthynnus yaito*. Often a species of nematod is found in the dorsal aorta of *Neothunnus macropterus*; the parasite causes the tissue of the canal to become thick and tough, giving it at the same time a yellowish tint.

FISHERY.

Fishing of the scombroid fishes has been pursued in our islands since the stone age. Bones of these fishes have been found in shell-mounds in different localities of our empire, as I have said already in a paper on the prehistoric fishing of our country (42). Bones of *Thunnus orientalis* are most abundant, and those of *Katsuwonus pelamis* and *Scomber japonicus* are frequently

met with, but those of *Auxis* and *Cybium niphonium* are rather rare. After the publication of the paper, I obtained through the kindness of Mr. GENSHICHI YENDO a spear-head, 214 mm long, lacking a barb, carved from a caudal fu-ray of a tunny. He collected it from a shell-mound of Miyagi-ken. A large caudal vertebra, recently discovered by Mr. AKIRA MATSUMURA in a shell-mound of Ogido, Ryukyu, belongs most probably to a species of *Gymnosarda*. A few vertebrae of *Euthynnus yaito* were also taken from a shell-mound of Iha, Ryukyu, by Prince KASHIWA ŌYAMA.

In some poems composed in the period of Tempyō-Shōhō (749–756) and cited in the "Manyōshyu", we learn that the tunny was caught at that time with spears as well as by means of hook and line. In the "Yengishiki", a classical work compiled between 900—927, we find names of several kinds of food, prepared from the mackerel and the striped bonito. These products were paid as tribute to the Imperial court and the Government from several provinces round our coasts. In that classical work, names of tunnies and seer-fishes are not mentioned, though tunnies at least were caught before that time. From the name of "sawara" for our common seerfish, we can guess that they have long been known to us, as that name in our old language means narrow abdomen, and it is just as old as the name "saba" for the mackerel, meaning narrow or minute teeth. From the twelfth century on, on account of many wars, most industries were disturbed and retrograded, until peace was restored by the consolidation of a central government in the seventeenth century, under the control of HIDEYOSHI TOYOTOMI. From an anecdote, however, we learn that an ingenius pound-net was planned and constructed in the period of wars in a bay near Sendai by a soldier, who got his idea from tactics in war. The device is a trap, with an elongated pound, the longer diameter of which is at right angles to the course of the leader. The pound as well as the leader have a certain curvature, which prevents the escape of fish at the mouth of the pound, and when the mouth is closed, at the bent corners of leaders, which are set in different directions. The apparatus first designed for the capture of the tunny has recently been employed in many other places for the capture of seerfishes, yellow-tails, etc. and it has proved to be superior to other types, having the longer diameter of the pound in the same direction as the leader. I is really remarkable that a fishing implement invented in the northeastern

part of our empire was introduced to other places. Generally the reverse is true, i. e. implements or methods invented in the central or western parts have travelled to the northeast.

Nearly all kinds of fishing apparatus are used for the capture of scombroid fishes, except casting nets and dredges. As many kinds of these fishes form large schools, the apparatus for their capture is generally large ; but its height is mostly under 60 m.

As most scombroid fishes are swift swimmers, fishermen try to retard their progress by scattering tole baits. These fishes are enticed to the artificial baits in motion. The mackerel is attracted to light at night, *Acanthocybium* to the shade of moored bundles of bamboo-stems or branches of *Paulownia imperialis*. Fishing with drift-nets is popular, but not good in clear waters, where other kinds of nets are also not suitable. In such grounds hook and line are the best means for catching.

Though the scombroid fishes are very widely distributed, their food is very plentiful, and their immature specimens are not molested by men, yet they become gradually scarce in old fishing grounds. Generally the scombroid fishes do not stay many days in the same place. It seems wise to change the fishing ground from time to time, not adhering to the same locality. Many unfortunate accidents occur in this hazardous occupation, as the fishing grounds are rough, lying general'y very far from the coast. Moreover the fishing apparatus is large, and the cost of the individual fish high, so fishermen try to haul in the whole apparatus even in case of sudden storms, and thus often fail to return to safety in good time. For the future development of the fishery of the scombroid fishes, it is desirable to build swift, sea-going boats, to discover good means of attracting these fishes, and to provide a suitable equipment for preserving these fishes, as they are much more perishable than other kinds. Fishermen detect the presence of these fishes by their leaping out of the water, by the movements of birds, the colour of the water, or peculiar waves or movements of the water at the surface of the sea. They use the troll line to detect the presence of these fishes in deep strata of water.

HOOK AND LINE.

In the mackerel fishery there are five kinds of hook and line fishery—rod

and line, casting line, ordinary hand-line, troll line, and long line—of which
the third and fifth are widely used. The ordinary hand-line is nearly
so long as the depth of the fishing ground. The gear consists of a spreader
or a lever, to which a sinker and a bag for tole bait are attached. The long
line is also largely used. It is a drift line, suspended from barrels by means
of buoy-lines, weighed sometimes with light weights. Hooks of these lines
are dressed with small pieces of sardine, saurel, or mackerel itself. The
artificial bait is seldom used. Gangings of the hand-line are of worm-gut.
The hand-line gear is essentially like that for the saurel.

In the seerfish fishery three kinds of hook and line are used;—hand-line,
troll line, and long line. The troll line is most popular and efficient. As
seerfishes are voracious, it is difficult to catch them with baits of little motion.
And as they do not come to the surface it is impossible to catch them with
rods. Good fishing grounds lie near straits or rocky banks. The troll line
for the common seerfish is like that for *Seriola quinqueradiata*. The length of
the gear is from about 40 to 200 m or more. Generally it is 60–100 m.
The line is tarred and on it numerous small lead sinkers are distributed.
When the line is short the weight is heavy, but if it is long, the weight is
comparatively light. The hook has a long shank and is angular in form.
As seerfishes have trenchant teeth, about 20 cm of the snood is made of a
metallic wire.

In the tunny fishery, rod and line, hand-line, troll line, and long line are
used. The long line is the most important. As tunnies are big and swift in
locomotion, the gear must be thick, stout, and long. When tunnies bite the
hook, they swim away at once furiously and irresistibly, until they are tired,
so that the gear must be sufficiently long to allow it. Lines are generally
made of hemp, and the lower end of the snoods at least is served with fine
thread or wire. To the gears for the tunny, sinkers are seldom added. The
minimum length of gear for the tunny is 200 m. The tunny long line is
very thick, strong and 400–500 m long, coiled in a basket. Each boat
shoots out lines of 10–15 baskets. The line is also a drift line, suspended
at the intermediate depth by means of buoy-lines of 10–25 m. As the ground-
line itself is thick and heavy, there is no need of sinkers. There are two
kinds of gangings,—short and long. The former is ca 12 m, and the latter

ca 37 m. A line from each basket is divided into three sections by five buoy-lines, two of which are attached to both ends. Each section is again subdivided into four by three gangings, the middle of which is the longer one. This long line is generally worked at night. The long line fishery of tunnies seems to have first been tried near the mouth of Tokyo Bay, about three centuries ago, and it was introduced in recent years to other parts of our country. Formerly a peculiar kind of fishing line for tunnies was used in the central and western parts. The line is about 200 m in length, and is wound round a small barrel, leaving about one quarter of the line to hang free. At the end of the free portion a hook dressed with a live bait is attached. A boat, with a crew of about half a dozen men, carries ten or more lines, which they leave in the sea to drift. When a tunny bites the hook, the barrel sinks at once, but as the wound part of the line becomes loose, the barrel arises whirling.

In the bonito fishery rod and line, troll line, and long line are used, but the first is most extensively used. As bonitos swim near the surface and do not descend to deeper strata of water, the fishing with rod and line is simple and convenient, no sinkers are used. It is remarkable that fishing of bonito with rod and line is done in our country and at Minikoy, a small island in the Indian Ocean, in nearly the same way. For the rod a bamboo-stem of about seven metres is used. Around the thicker end of the stem a string is roughly wound to prevent the hand from slipping. The line is nearly the same in length as the rod, and about 30 cm of the terminal portion is dyed with indigo. The hook lacks the barb, and is dressed with living sardine or anchovy. Fishermen hold their rods in such a way as to allow the living bait to swim at the surface of the sea. With artificial bait short rods of about three and half metres and a line of 120 cm long and of thick diameter are used. While fishing, living fish are thrown as tole bait far and near.

DRIFT NETS.

Drift nets for different scombroid fishes differ in the size of meshes, depth, length, and the thickness of the twine. For small fishes drift nets are gill-nets, but for tunnies there is no gill-net. Drift nets for scombroid fishes are generally worked in warm seasons. Drift nets for tunnies and bonitos are

shot at the surface of the sea; but those for the mackerel and seerfishes are suspended in more or less lower strata of water, by means of buoy-lines of some length. These nets are worked at night. Sometimes gill-nets are shot with both ends bent towards the school of fish and they are driven towards the net. When the tunny strikes the net, it yields to the movement of the fish, and forming a pocket passes over the float line and is hung back. Thus when the height of the tunny drift net is too high, the capture is not satisfactory. The tunny drift net is chiefly used on the Pacific coast of the northeastern part of Hondo.

SEINES.

Seines for scombroid fishes are also chiefly used in the warm season. The size of the meshes is proportional to that of the fish to be caught; but it is very small in the seine for our common seerfish, or its hunt is made of coarse cloth, woven with strong thread. This is to prevent the penetration of the jaws of the fish into the netting, lest the seine should be damaged by their trenchant teeth. Seines for scombroid fishes are mostly 70–85 m deep, and 500–1000 or more long. In some of these seines the wings are made of straw nettings. Seines for the common seerfish are used in the Inland Sea only, and are hauled towards the land, while those for the other scombroid fishes are hauled into boats. Tunnies captured with seines are *Thunnus orientalis* and *Neothunnus macropterus*. The striped bonito is sometimes captured with seines. Before the development of seines for tunnies and bonitos schools of fishes were surrounded with a long wall of net, and then the fish were scooped out with a kind of large dip-net.

POUND-NETS.

Special pound-nets are built for the capture of *Thunnus orientalis* and *Neothunnus macropterus* in warm seasons, when these fishes migrate northward. In some places pound-nets for the capture of tunnies in their southern migration are erected; but these are very few in number, and are not so important as the other. The pound-nets for *Thunnus orientalis* in their northern migration are very important, and very abundant. Other scombroid fishes are also caught in large numbers in pound-nets; but their time of appearance is rather short, or occasional, and the expenses of pound-net fishery can not be sustained by these fishes only.

There are different types of pound-nets for the capture of tunnies developed at different parts of our empire. But as I have stated before, a type called "daiboami", developed near Sendai is at present the most advanced one. It resembles in form the madrague of the Mediterranean, but in our pound-net the bottom is entirely closed with netting, and there are no dividing walls. The movement of the fish is observed by the boat crew by signals from a watch-tower, on a wooden frame-work, erected from the sea-bottom, or on a precipice near by. At the strait of Tsugaru the watchman observes the fish by transmitted light from the sea, seated under a cover of matting, which partly hangs over the sea, from the side of his boat. In the case of the daiboami, the watchman takes his post just opposite the entrance of the pound. In other more simple cases the watchman is seated in the boat at the mouth. When a school of fish enters the pound, its entrance is closed by lifting up the sunken netting, connected with the bottom of the net, and the bottom is hauled over from one end to the other, the bunt. The depth of water at the entrance of the pound should be more than 15 m. Effective pound-nets for the tunny are about 30 m deep at their entrance. The size of the pound-net generally in use is 430 m in circumference, and ca 150 m in the longer diameter. The mackerel and the common scerfish are caught in pound nets for *Seriola quinqueradiata* or miscellaneous fishes.

Classification.

So far as I have studied, the natural affinities of fishes can not be ascertained from the examination of external characters only. Some authors classify the genus *Auxis* near *Scomber*, as the two dorsals are separated, but in reality these two genera are at both extremities of the phylum of the scombroid fishes.

Order TELEOSTEI.

Suborder **Acanthopterygii**.

Family SCOMBRIDAE (s. str.) Günther.

Scombridae (in part), Günther, 1860.
Scombrinae, Jordan & Evermann, 1896; Starks, 1910.
Scombridae (in part), Boulenger, 1904; Regan, 1909.
Scombridae, Kishinouye, 1915.

Body fusiform, and more or less compressed. Head pointed at the anterior

end, its upper surface flattened and naked, but the opercles are scaly. Caudal peduncle rounded in cross-section, having no lateral keel. A pair of small keels are found on each side of the tail. Lateral line gently curved, wanting marked bendings or undulations. Adipose eyelids present. Scales cycloid, often finely crenulated or more or less ctenoid at the posterior margin. Corselet indistinct. The scales at the pectoral region have the same structure as those in the remaining regions, but the former are only a little larger than the latter. The former are not covered with a connective tissue membrane. Post orbital scales rather large, unequal in size. In the ventral half of the body, rows of scales run nearly parallel to the ventral median line of the caudal region.

Mouth large with minute teeth. Tongue very small and smooth. The maxillary is almost entirely covered by the preorbital, and the supplementary bone at the posterior end is very small, slender and insignificant. Premaxillaries are very slender and weak. Gill-rakers very numerous, long, slender and much compressed, with two rows of fine diverging pairs of long denticles on the inner side. Gill-lamellae very short at the angle of gill-arches. Branchiostegal membranes very broad and overlapping each other at the symphysis.

Opercle short, and notched at the posterior margin. Subopercle very narrow. Preopercle comparatively large, rounded and expanded at the lower posterior corner. Clavicular ligament is inserted at the posterior end of the exoccipital. Fins not well developed. Interspinous bones are weak and slender. Fin-rays are transversely articulated. The second dorsal is lower than the first and the two dorsals are distinctly separated from each other. The first spine of the first dorsal is shorter than some succeeding spines. The second dorsal and the anal are covered with small elongated scales.

The abdominal cavity is ellipsoid in cross-section, with the longer diameter vertical. Peritoneum generally black. Pylorus ascending. Pyloric coeca numerous, arranged in many longitudinal rows. They are rather large, opening directly to the duodenum, and are loosely connected with connective tissue fibres. Alimentary canal long and folded. The liver is a small triangular mass, occupying the left anterior corner of the abdominal cavity. Kidneys thin, elongated and divided into two before the pharyngeal muscle, which is inserted into the third or fourth vertebra, or into both.

Skeleton thin, but firm. Skull elongated and the greater part of the fron-

tals lies directly under the skin. Occipital crest low and small. Sphenotic and opisthotic not visible at the dorsal surface of the skull. The exclusion of the opisthotic from the dorsal surface of the skull is quite the same as in the Carangidae. Accessory lateral ridges are found on the dorsal surface of the skull. Occipital condyle is remarkably hollow. Paroccipital condyles are oblique, turned externally, and are separated from each other by the foramen magnum. Articulating facets of the skull with the atlas are on both sides of the foramen magnum and do not form a part of the margin of the foramen. Vertebrae generally 31 in number, they differ but little from each other in form, size, different processes, etc. No transverse process. Lateral ridges in the anterior vertebrae pass gradually to the ventral ridges in the vertebrae of the posterior region.

First vertebra, the atlas, is remarkable in having a pair of large, articulating processes projecting, instead of declining obliquely backward, and also in having the neural process attached to the centrum (fig. 30). In precaudal vertebrae the neural canal is entirely covered with an arching septum to protect the spinal cord, and is separated from the ligament of the vertebral column occupying the dorsal part of the neural canal. The neural process of the precaudal vertebrae is more flexible and more feeble than that of the caudal vertebrae. In the caudal vertebrae prezygapophyses and the anterior ventral processes are especially well developed. The last vertebra and the hypural bones are not consolidated together. No auxiliary intermuscular bones are found in the cephalic region. Ribs are not much compressed and hang down the abdominal wall. Pelvic girdle very small. Antero-inferior corner of the dorsal flattened part of the hyomandibular is free and rounded (fig. B). The free trenchant edge of the palatine is armed with a row of teeth in the genus *Scomber*. In the lower piece of the post-clavicle we distinguish the broad proximal part with a short slender anterior process, and a long slender distal part. Ethmoid is narrow and produced anteriorly beyond the paired lateral processes. The basibranchial chain is narrow, laterally compressed, elongated, and nearly straight.

This family is more or less related to the Carangidae, in the presence of the adipose eye-lids, free spines before the anal fin, transversely articulated fin-rays, and opercle with a dorsal notch, narrow subopercle, etc. But the family is distinguished from the Carangidae in wanting characters of the Perciform

fishes—narrow premaxillary which is not protractile and wants a dorsal process, and a small supplementary bone attached to the posterior end of the premaxillary. This family has remote relations to the Cybiidae. The genus *Grammatorcynus* of the Cybiidae has the same number of vertebrae as the mackerels, and pyloric coeca are also more or less alike.

STARKS (69) rightly remarks that " if we could eliminate the genus *Scomber*, the family (Scombridae in wide sense) would be much more compact, as it stands farther from the other genera than they do from each other."

Mackerels are rather small, grow to a length of about 40 cm. and a weight of about one kg. They swim generally in the middle or lower layers of the coastal water, and enter into bays and inlets, in shoals. Widely distributed in temperate and subtropical regions.

Key to the genera of the Scombridae.

Body elongated and fusiform, vomer and palatines toothed. . . . .*Scomber*.
Body deep and compressed, vomer and palatines toothless, gill-rakers very
   long, visible from the gape of the mouth, interspinous bones of the second
   dorsal and the anal are flattened. . . . .*Rastrelliger*.

Genus **Scomber.**

Scomber, Linnaeus (s. str.) 1758; Cuvier, 1817.

Teeth minute, in both jaws in one row, on the vomer in paired oblique patches and on palatines in one row.

Only two good species are known, and only one species is found in the Pacific Ocean.

Scomber japonicus Houttonyn.

Saba.

Figs. 1, 7, 16, 28-30.

Scomber japonicus Houttonyn, Memoires de Harlem, XX. 331. 1782; Lacépéde, Hist·
   Nat. Poiss. III, 45, 1802; Cuv. & Val. Hist. Nat. Poiss. VIII, 51, 1831; Kishinouye,
   Sui. Gak. Ho, I, 4, Pl. 1, Fig. 1, 1915.
Scomber pneumatophorus Schlegel, Fauna Japon., Poiss. 94, Tab. 47, Figs. 1, 2, 1850.
Scomber saba Bleeker, Verh. Bat. Gen. XXVI, 95, 1857.
Scomber janesaba Bleeker, Verh. Bat. Gen. XXVI, 96, 1857.
? Scomber tapeinocephalus Bleeker, Verh. Bat. Gen. XXVI, 97, Tab. 7, Fig. 2, 1857.
Scomber colias Kishinouye, Journ. Fish. Bureau, II, 1, Pls. I, II, 1893.

D. 9-12, 12, 5.   A. 1, 12-13, 5.   Vert. 14+17.   Gill-rakers 13+23.

Body fusiform and compressed, its height nearly equal to the length of the head. Teeth minute, about 60 in each jaw. The scales in the dorsal half of

the body are arranged in nearly horizontal rows, while those in the ventral
half are arranged in oblique rows, more or less parallel to the ventral median
line of the caudal region, i. e. ventral outline.

Air-bladder large and fusiform, pointed at both ends. Pyloric coeca near
the pylorus are longer and more numerous than those removed from it. The
pyloric portion as well as the duodenum are ascending, the latter runs from left
to right, occupying the most anterior border of the abdominal cavity. At the
right corner of the cavity the duodenum passes to the small intestine, which
runs backward, then bent forward, a little before the anus, and it is bent again
backward. A little behind the second bend the small intestine ends and is fol-
lowed by the rectum.

About three small veins from the pyloric coeca form the portal veins ; two
veins running upon the dorsal surface of the stomach do not form the hepatic
portal veins, but pour directly to the ductus Cuvieri.

A free spine before the anal is about one fourth the length of the first anal
spine. Each dorsal or anal finlet is sometimes connected with the body by
a membrane behind it.

Dark branching zigzag bands, about thirty in number, are found in the back.
The number of these bands is nearly the same as that of the vertebrae and their
course generally corresponds or coincides with the contour line between myo-
tomes. Back bluish green, the colour becoming lighter towards the tail. Belly
silvery white with irridescent lights. Fins greyish more or less washed with
yellow. The space between the posterior nostril and the eye is nearly colour-
less and transparent. The dorsal fins and dorsal finlets, pectorals, and the caudal
are greyish, and sometimes washed with yellow. The ventrals, anal, and anal
finlets are colourless.

Among our common mackerel we find two different types which fishermen
distinguish under the names of " hirasaba " and " marusaba ", meaning res-
pectively flat and round. In the internal structure we can hardly distinguish
them ; but in some external characters and habitat they differ more or less. A
comparison of fig. 28 with fig. 29 will give the reader a very good idea of these
differences. However, as there are many intermediate forms between these two types
of forms, I can not take them as different species. In the typical hirasaba we
count 9 spines in the first dorsal, while there are 11-12 in the typical maru-

saba. Moreover in the former variety the dark coloured bands in the back run down beyond the lateral median line. In that variety the caudal fin is yellowish. The fish lives near the coast, but in deeper layers of water. Its flesh is more oily and palatable. In the other variety which is also called "gomasaba" the dark coloured bands in the back are found, only above the lateral median line. On that line there is a row of round spots, and below the line there are numerous greyish spots. It is chiefly found in off-shore grounds and in shallower strata of water, making larger shoals than the former variety.

This species inhabits rather littoral waters, and its range of distribution in our country is very wide, from Karafuto to Taiwan. On our coast this species is rarely found in layers of water deeper than about a hundred metres. We observe more or less the bathybial as well as latitudinal migration of the mackerel. In spring the mackerel enters the Inland Sea, and in summer it is caught off Notasan, west coast of Karafuto. In winter it is caught near Tanegashima, Kagoshima-ken. In Hondo it is caught all the year round, but large catches are expected in summer and autumn. It is also caught abundantly on the east coast of Chosen, especially near the Channel of Chosen. At the Channel of Chosen, i. e. at the southern entrance of the Japan Sea, mackerels make thick shoals in spring and autumn. Two hundred and sixty thousand mackerel with a part of saured were caught in a haul with a purse seine. Sometimes two millions of mackerel are landed in the port of Hōgyoshin near Fusan in one day. Mackerel are caught in twilight when they come to shallower layers of water. In cloudy weather they often rise to the surface.

Adult mackerel approach the twenty metre line shoreward, and are distributed a little beyond the two hundred metre line. They are never found in the Kuroshiwo, being found in waters of 10–20° C. On a cold day and during the cold season mackerel are found near the bottom of the sea. The optimum density for the mackerel is 1.025.

Mackerel spawn in May. Fry and the immature fish are found among those of the sardine, anchovy, and the saurel. They grow very rapidly, feeding on fries of other fishes. When they are about 36 cm in length and $\frac{1}{2}$ kg in weight, they are ripe for the first time. The age of these fishes is not exactly known. They may be two or three years old. Fish of about 60 cm long and $1\frac{1}{2}$ kg in weight are very large and rare.

In olden times fishermen attracted fish with torch-light, but at present electric lamps, acetylene light, etc. are used. The light attracts many planctonic animals near the surface of the sea, and they in turn attract the mackerel, and other animals such as saurel, calamaries, etc., gradually towards the surface of the sea. Thus the time used in catching the mackerel is greatly economised. Besides light, tole bait is much used to attract the fish. Salted mantis-shrimp is chiefly used for the purpose. Long lines and drift nets are extensively used in the Japan Sea. Encircling seines, such as the purse seine and "shibari-ami" are chiefly used in the southern part of Chosen.

The mackerel fishery is carried on on a rather small scale, with hand lines, long lines, or drift nets. The hand-line is most extensively used. The gear consists of a line of about 100 m, two brass outriggers or spreaders, each ca 30 cm long, spreading from both sides of a conical lead, three to four hundred gr in weight. A worm-gut snood 2 m long is generally fastened to each outrigger, with a small hook at the distal end. A small bag is usually fastened to the lead to hold tole bait. Immature mackerel or yearlings are caught in large quantities with haul-seines in shallow waters.

Genus **Rastrelliger** Jordan & Starks.

Rastrelliger, Jordan & Dickerson, 1908.

Body deeply compressed. Mouth large, maxillary nearly reaching the posterior edge of the eye. Dentition feeble, the vomer and palatines toothless. Gillrakers exceedingly long and numerous. Intestine very long, bent several times. Found in tropical and subtropical regions of the Indo-Pacific.

Rastrelliger chrysozonus (Rüppel).

Gurukun (Ryukyu Is.), murehji (Naha, Ryukyu).

Fig 63.

Scomber chrysozonus Rüppel, N. W. Fische, 37, Taf. XI, Fig. 1, 1838.
Scomber microlepidotus, Day, Fish. India, 250, Pl. LIV, Figs. 3—6, 1875—78; Kitahara, Journ. Fish. Bureau, VI, 5, Pl. III, Fig. 5, 1897.
Scomber kanagurta, Jordan and Richardson, Mem. Carnegie Mus., 1909.
Rastrelliger chrysozonus, Kishinouye, Sai. Gaku. Ho, I, 8, 1915.

D. 10, 12, 5. A. 12, 5. Vert. 13 + 18.

In freshly preserved specimens in formalin the back is bluish with greenish lustre in the anterior part, a row of greyish dots on each side of the base of

the dorsals, two greenish grey longitudinal bands above the lateral line, and two golden longitudinal bands from the base of the pectoral. Cheeks and belly silvery. Two dorsals and dorsal finlets greyish, and the anal and anal finlets colourless or tinged with yellow. Peritonium black. Interspinous bones of the second dorsal and anal are flattened, and laterally compressed.
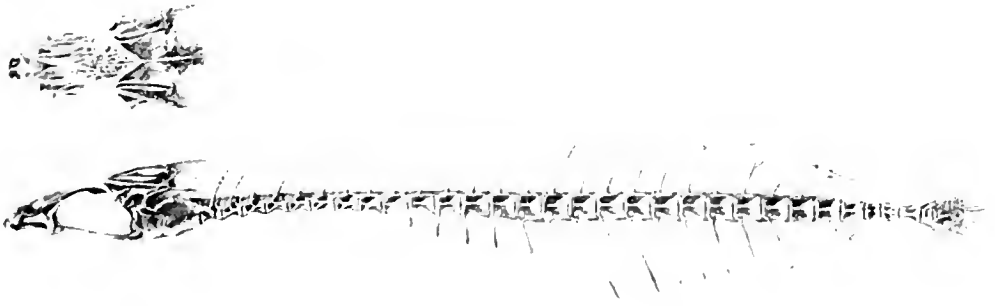
Fig. W. Skeleton of *Rastrelliger chrysozonus*. 3 5.

Membrane connecting the branchiostegals is very wide. The last branchiostegal is bent like the letter L. Pyloric cocca are more or less united to numerous groups at their root, and each group to the duodenum with a common orifice. In the caudal vertebrae thin paired ridges are found on the ventral side.

It is said that shoals of this fish are observed on a calm day seething near the surface of shallow water, busily feeding on minute planktonic organisms. The fish are very alert and not easy to catch. In the Ryukyu Islands small individuals are caught in summer, and large ones in winter.

DAY found that the ova ripen in March. It grows to a length of ca 35 cm.

Widely distributed in tropical and subtropical regions of the Indo-Pacific. Specimens from southern China, Formosa and Truck Is. were examined.

Family CYBIIDAE Kishinouye.

Body generally elongated and compressed, but plump in the genera *Sarda* and *Gymnosarda*. Caudal peduncle pretty thick and nearly rounded in cross-section, and provided with a large keel on each side. The keel is covered with

elongated scales, except in *Sarda*. Head elongated with a long snout. Mouth large, and wide, the maxillary extending beyond the hinder margin of the eye. Eyes generally small. Posterior margin of the upper jaw, or that of the jugal in the strict sense, is more or less rounded, as the supplementary bone is well developed. Teeth in jaws are in one row only. They are large, curved inward, and compressed with trenchant edges. Tongue large, rounded, convex, but the glossohyal is comparatively small and narrow.

Corselet small, more or less distinct, but its scales are not much specialised. Scales small, generally cycloid, and often concealed under the skin. Sometimes scales disappear entirely outside of the corselet, lateral line, and caudal peduncle. Lateral line sinuous, particularly in the posterior portion of the body, and the line is often furnished with many minute branches (figs. 31, 32, 35, 61).

Fins generally small, especially ventrals, but the caudal fin is comparatively large. Fin-rays are not transversely articulated in the adult fish. Pectorals are comparatively small. First dorsal low and long, gradually descending posteriorly, and its spines are rather weak. First dorsal has generally a straight or more or less convex outline, except in *Acanthocybium*. The first spine of the first dorsal is shorter and weaker than some following spines. There is scarcely an interspace between the first and second dorsal, and the latter is generally a little higher than the first dorsal, except in *Grammatorcynus* and *Acanthocybium*.

Peritoneum more or less dusky. Stomach long and narrow, with 12–30 longitudinal folds inside. Pylorus opens very near the cardiac portion; it is long, narrow, descending, and communicates with a narrow opening at the ventral side near the distal end. Duodenum curved or twisted, enlarged with two or more branching pyloric tubes high at the posterior side, disposed more or less in a whorl round the intestine. Pyloric coeca at the end of the terminal branch of these tubes branch dendritically. Intestine is often very long and bent several times.

Skeleton is generally spongy, light, and more or less fragile. It is more or less solid in *Acanthocybium* and quite firm in *Gymnosarda*. Skull elongated, with low and weak occipital crests. Vomer is generally flat, more or less produced, and covered with villiform teeth, except in *Sarda* and *Gymnosarda*. Anterior lateral corner of the ethmoid is more or less produced.

foramen between the basioccipital and parasphenoid is small and opens nearly in a horizontal plane. Paroccipital condyles touch each other at the median line, and the occipital condyle is only slightly concave. Number of vertebrae is 31-64, generally more than forty, and varies greatly even among closely allied species. Relative number of the caudal and precaudal vertebrae is also variable. Differentiation of vertebrae is a little more advanced than in the Scombridae. Sometimes I found abnormal cases in which two or more vertebrae fused together. Longitudinal grooves in vertebrae are deep, and thus the cross-section of most vertebrae show a six-radiating figure (figs. 8-12). In some posterior precaudal vertebrae a short haemal process is found. Neural process is broad in some anterior precaudal vertebrae, and the process of the first vertebra is free from the centrum. The last caudal vertebra is consolidated with the hypural bones, and forms a fan-shaped bone with a notch at the median posterior corner. Hypural spine very prominent, but rather small in *Sarda* and *Gymnosarda*. One or two auxiliary intermuscular bones are found in the occipital region, where the clavicular ligament is inserted. Intermuscular bones are weakly developed at the anterior portion of the body only, connected by a few and poor tendons.

Gill-rakers are very poorly developed in the Cybiidae. They are short, not much compressed, generally a little more than ten in number, and entirely absent in *Acanthocybium*. A few gill-rakers are found near the angle of the second branchial arch in some forms. Two or more rows of short denticles are found on the inner side of gill-rakers. Ribs are found on the dorsal wall of the body-cavity, as myotomes are bent with acute angles. Pelvic girdle narrow and elongated. Generally the lower piece of the postclavicle is nearly straight.

The vascular system of the Cybiidae has many characteristics :—development of the renal portal system from dorsal segmental veins in the precaudal region, origination of the genital artery from the dorsal aorta, remarkable separation of the dorsal aorta from the cardinal vein with the intervention of rete mirabilis of the renal portal system between them. Ureters of both sides are entirely separated. Kidneys elongated. Muscles nearly colourless, but the median superficial lateral portion is reddish. This reddish portion becomes rather thick posteriorly (fig. 17).

The posterior side of the preopercle is generally a little concave in *Cybium*

and *Grammatorcynus*. The second basibranchial is bent downward at the middle.

Neural and haemal spines of the caudal vertebrae are not straight, but more or less curved. The haemal arch in the precaudal vertebrae is short, and turned anteriorly, the haemal spine is little developed in the precaudal region.

Seerfishes are generally active when the sea is rough, and the current strong, also in the morning and in cloudy weather. They often leap out of the water, and when they are impounded in a net, they try to get out of it through the meshes at the bottom, especially at night. Generally they swim near the shore, but some of them are chiefly pelagic. Many of them assemble and form big shoals, and approach the shore in the breeding season. They are predaceous fish, they feed on small fish such as sardines, anchovies, saurels, mackerel, and sometimes shrimps and calamaries. Found in the temperate and tropical seas. Many of them are excellent food-fish. Small immature specimens of the Cybiidae are more or less flat and broad, larger specimens are thick and elongated, quite contrary to the case of the Katsuwonidae.

This family is related on one hand to the Xiphiidae in the reticulate gills, absence of gill-rakers, small narrow scales, etc. through the genus *Acanthocybium*, to the Scombridae through the genus *Grammatorcynus*, and to the Plecostei in the form of the body, osteological structures etc. through the genera *Sarda* and *Gymnosarda*. This family comprises the Scombrinae, Acanthocybinae, and Sardinae of STARKS.

Key to the Japanese genera of the Cybiidae.

Body elongated, teeth in jaws trenchant, vomerine teeth present.
    Gill-rakers none, gill-lamellae reticulated, intermuscular bones inserted on
        ribs . . . . *Acanthocybium.*
    Gill-rakers present, gill-lamellae not reticulated, intermuscular bones in-
        serted on respective vertebrae.
            Two lateral lines on each side of the body . . . . *Grammatorcynus.*
            Only one lateral line on each side of the body. *Cybium.*
Body plump, teeth in jaws with rounded edges, vomerine teeth absent.
    Body covered entirely with small scales, tongue toothless . . . . *Sarda.*
    Body naked outside of the corselet, tongue covered with villous teeth, pala-
        tines are also toothed . . . . *Gymnosarda.*

Genus **Acanthocybium** Gill.

Acanthocybium, Gill, 1862; Lütken, 1880; Jordan & Evermann, 1896.

This genus comprises a rather aberrant form, more or less related to the Xiphiidae. Body elongated, more or less compressed, and covered with small narrow scales. Premaxillary produced anteriorly. Preorbital forms the posterior half of the upper jaw. Teeth triangular, compressed, and closely set. Branchial lamellae are reticulated at the proximal part. Gill-rakers absent. Intermuscular bones are inserted on ribs. The first rib is found on the second vertebra, not on the third as in the other. Moreover the rib is shorter than the intermuscular bone inserted on it. No auxiliary intermuscular bone, and the first intermuscular bone is inserted on the first vertebra. Pelvic girdle broad.

Pelagic and predaceous fish of about two metres. Tropical and subtropical seas of the Pacific and Atlantic.

Acanthocybium solandri (Cuv. & Val.)

Kamasusawara, ōkamasu, okisawara, sawara (Kochi-ken, Kyushyu,

Ogasawara Is.), tessahku (Taiwan), tōjinsawara.

Figs. 10, 31, 39.

Cybium solandri, Cuv. & Val., Hist. Nat. Poiss. VIII, 192, 1831.

? Cybium sera, Bennett, Beechy's Voyage, Fish, 63, Pl. 20, Fig. 2, 1839.

Acanthocybium solandri, Jenkins, Bull. U. S. Fish Com., XXII, 441, 1904; Kishinouye, Dobutsu. Zas. XX, 2, Pl. 2, Fig. 2, 1908.

? Acanthocybium forbesi, Seale, Philip. Journ. Sci. Biol. VII, 283, 1912.

Acanthocybium sara, Kishinouye, Sui. Gak. Ho, 1, 9, Pl. 1, Fig. 2, 1915

B. 7. D. 26, 11, 9. A. 11, 9. Vert. 23-33+31. Gill-rakers O.

Body elongated and compressed, covered with thin small lanceolate scales. Corselet indistinct. First dorsal well developed, descending near the posterior end, but its greater part has nearly the same breadth. Second dorsal and the anal very small. Caudal fin lunate and powerful. Lateral line is suddenly and strongly curved, under the middle of the first dorsal. Many vertical branches are given off from both sides of the lateral line. Those branches found in the posterior half of the body are longer and more numerous. In each jaw about 50-55 triangular teeth, which gradually increase in size posteriorly. Vomer and palatines with villous teeth. First rib on the second vertebra (STARKS (69) found the first rib on the third).

Stomach conical and very long, reaching a little behind the anterior end

of the rectum. Pylorus short, curved, and descending, duodenum more or less widened, with three or four pyloric tubes, the shortest of them is at the anterior side, and the longest is furthest removed from the pylorus. Intestine is narrow and straight. Air-bladder long, more or less spindle-shaped, running the whole length of the abdominal cavity. Urinary bladder is very long and is found attached to the ventral wall of the air-bladder, and above the rectum in the abdominal cavity. Two ureters unite to a median canal near the end of the blended kidneys, and open to the posterior end of the bladder.

This species is found chiefly in the clear warm water of the tropical and subtropical seas, and is found at the mouth of Tokyo Bay in the east, from Shimane-ken, Kyoto-fu, and at the north of the southern coast of Chosen. A few examples are nearly always found in the markets of southern Kyushyu in summer and autumn. In the Ogasawara Islands this fish is cut into pieces and dried after boiling, or is preserved in hermetic cans.

Pelagic fish, do not make a school. They feed on pelagic fish and calamaries. Voracious and easily attracted with natural or artificial baits. Caught with trolling lines, which are dressed with live or salted saurel, or with spears after alluring with artificial fish, made of wood or canvas to imitate flying fish or its own species. In Kochi-ken and Kagoshima-ken the fish is attracted to the shade of a large bundle of bamboo stems or branches of some light wood, moored in off-shore grounds, specially constructed for the purpose.

The colour of the fish is steel-blue in the back, with about thirty dark transverse bands, which are distinct in young fishes, and in the adult fish when excited. Dorsals, pectorals, and caudal are blackish, while the ventrals are dusky.

A fish about one and half metres in length, and about seventeen kg in weight, caught off Hachijoshima in June contained nearly ripe ovaries. Another fish of similar size, caught off the Ogasawara Islands in August, 1919 contained much more slender ovaries than the preceding. An immature fish, 28 cm in the total leng)th was caught by a bonito-angler off Daiozaki, Miyeken on Aug. 19, 1917.

When speared the fish darts against the bottom, and then floats to the surface dead.

A large species of distomum, about 8 cm in length, is almost always found in the stomach.

Genus **Grammatorcynus** Gill.

Grammatorcynus, Gill, 1832; Klunzinger, 1884.
Nesogrammus, Evermann & Seale, 1807

Body elongated, compressed, and covered with small scales. Corselet indistinct. Mouth rather small, maxillary not reaching the middle of the eye. A deep groove in the skin from the corner of the mouth, as in many other forms of the mackerel-like fishes. Tongue broad. Teeth elongated, trenchant. Villous teeth on the vomer and palatines. Two dorsals continuous. Second dorsal and anal are divided into finlets in the hind part, and are lower than the first dorsal. Gill-rakers short and strong. Opercle with a shallow notch at the posterior margin. The lateral keel of the caudal peduncle is low and small, covered with a row of pored scales. Two lateral lines on each side of the body.

Fish of this genus are also an aberrant form of the Cybiidae. The insignificant keel on the caudal peduncle, the rather small number of vertebrae, indistinct corselet, slightly notched opercle, backward origin of the first dorsal etc. connect this genus more or less with the Scombridae; but trenchant teeth, continuous dorsals, large broad tongue, renal portal veins, short strong gill-rakers, descending pylorus, dendritic tubes to which pyloric coeca open, bent second basibranchial, etc. indicate that this genus is much closer to the other genera of the Cybiidae.

Only one species is known from the tropical seas and adjacent waters of the Indo-Pacific region.

Grammatorcynus bilineatus (Rüppel).

Kusarah.

Figs 8, 62.

Thynnus bilineatus, Rüppel, N. W. Fische, 39, Taf. 12, Fig. 2, 1819; Günther, Cat. II,
366, 1860.
Grammatorcynus bilineatus, Gill, Proc. Ac. Philad. 125 1862. Klunzinger, Fisch. Roth Meer,
113, 1884; Kishinouye, Sui. Gak. Ho. I, 86. 1915
Nesogrammus piersoni, Evermann & Seale, Bull. Bur. Fish. XXVI, 61, 1907.

D. 12, 9, 7. A. 10, 7. Gill-rakers 5+16. Vert. 13+18.

Body elongated, fusi-
form, covered with small
thin scales. The cheeks
are covered with many
small scales. Top of the
head flat, and the greater
part of the frontals is direct-
ly covered by the skin.
Eyes large. Vomer flat-
tened, villous teeth in a
median group. Occipital
crest low. Opisthotic
forms a small portion at
the posterior dorsal portion
of the skull. No auxiliary
intermuscular bone. The
first dorsal interspinous
bone seems to belong to the
myotome of the second
vertebra, as in the case
of the Scombridae. The
second dorsal and anal are
covered entirely with elon-
gated narrow scales. The
ventral or the external side
of pectorals is also covered
with similar scales. Teeth
in jaws are small with
trenchant edges, about 27
in the upper, and about
20 in the lower. The
condylar facet of the
basioccipital is slightly
hollow and oblique. Arti-
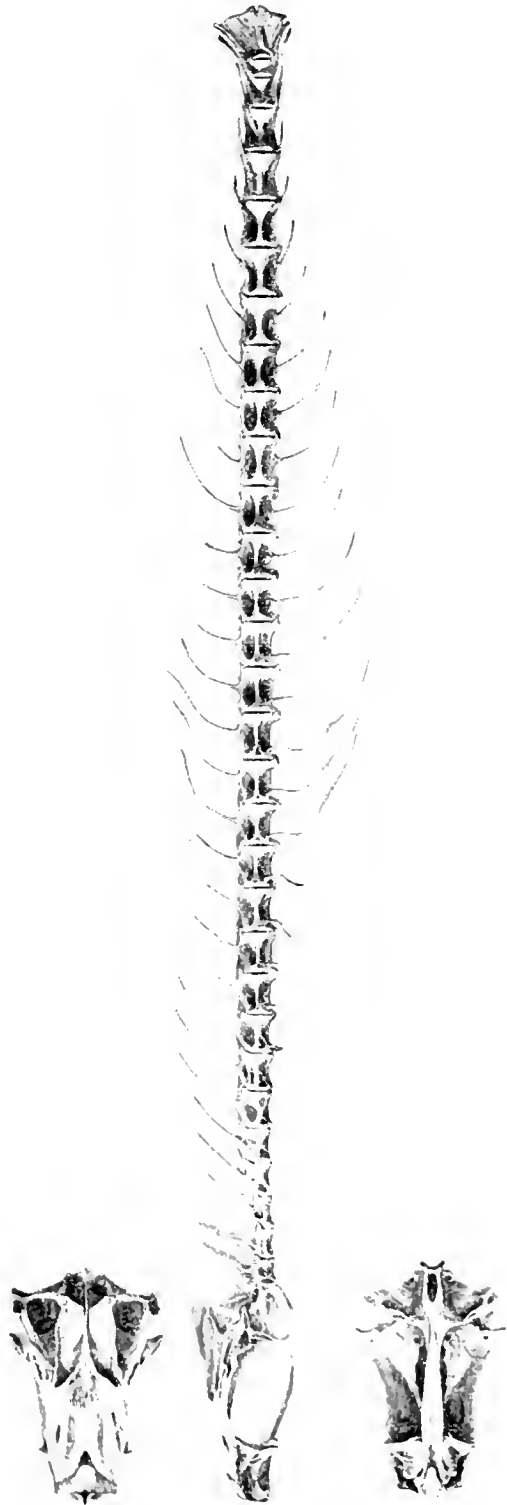
Fig. X. Skeleton of *Grammatorcynus bilineatus*. 3/5

culating facets of the exoccipitals are nearly horizontal processes not united at the middle, they project backward over the condylar facet. The neural process of some anterior vertebrae is noticeably broad.

Stomach coecal, rather short, with about nine longitudinal folds inside. Pyloric portion descending, short, and thick walled, with about five longitudinal folds inside. Duodenum obliquely descending. Pyloric coeca short, numerous and branching. These are more or less grouped into several clusters, chiefly arranged on special tubular outgrowths. Posterior into the duodenum the intestine is nearly straight. The liver is three-lobed, the middle lobe shortest, while the right lobe is longest. Ureters are united at the posterior end of the blended kidneys. Urinary bladder small, with a short dorsal median septum, near the anterior end. Air-bladder well developed.

The vulgar name of this fish is kusarah in Ryukyu, meaning perishable, as the fish decomposes very quickly. The fish is said to be inferior in taste. Specimens examined were from the Marshall and Ryukyu Islands. Most of them are about thirty cm. in the total length.

Genus **Cybium** Cuvier.

Cybium, Cuvier, 1829, Günther, 1961.
Scomberomorus, Lacépède, 1802 ; Dressler & Fesler, 1889 ; Jordan & Evermann, 1896.

Body elongated and more or less compressed, covered with thin small scales, or sometimes naked outside of the corselet. Top of the head more or less convex. Posterior nostrils elliptical. Mouth large, upper jaw extending beyond the hind margin of the eye. Posterior end of the upper jaw rounded, and its lower margin nearly straight, being formed by the premaxillary only. Teeth large, compressed, and curved inward with trenchant edges. Gill-rakers few and short. Dentigerous ossicles on the branchial arch are in two rows. Skull elongated, with its dorsal surface somewhat flattened, and entirely covered with muscles. Occipital crest low, but continuous to the median ridge of the frontals. Vomer projects as an oval flat process, and is covered with villous teeth. Pylorus long and slender. Pyloric coeca dendritic, more or less coarse, and open to branches arranged on both sides of pyloric tubules.

Fishes belonging to this genus are generally large, and move in shoals, inhabiting temperate and tropical regions, where industries of some importance

are established upon them. They are generally good in taste, the flesh being fatty and delicate in structure.

In 1803 LACÉPÈDE created a new genus *Scomberomorus* for a fish of this genus, by examining an inaccurate copy of a sketch by PLUMIER, which represented the two dorsals as if they were connected together. But afterwards LACÉPÈDE found that his *Scomberomorus plumierii* was a synonym for *Scomber regalis* BLOCH ; so that he withdrew the genus afterwards, and omitted it in the index of his work. Moreover the following diagnosis of the genus written by LACÉPÈDE is quite inappropriate for any fish of the Cybiidae. The diagnosis is written as follows :—

"Une seule nageoire dorsale ; de petites nageoires au-dessus et au-dessous de la queue ; point d'aiguillons isolés au-devant de la nageoires du dos".

I have found the five following species in our waters. Though JORDAN and RICHARDSON (29) mention the name of *C. kuhli* in their catalogue of Formosan fishes, I was unable to find the species.

Key to the Japanese species of the genus *Cybium*.

Lateral line simple, air-bladder present.
    Pectorals pointed, many transverse bands on the body . . . .*C. commerson.*
    Pectorals large and rounded, indistinct spots in one or two rows. . . . .*C. chinense.*
Lateral line with numerous fine branches, air-bladder absent.
    Tongue toothed, lateral line slightly undulating.
        Height of the body nearly equal to the length of the head, second
            dorsal long. . . . .*C. guttatum .*
        Height of the body much greater than the length of the head. . . . . . .*C. koreanum.*
    Tongue naked, lateral line with a marked curve. . . . . *C. niphonium.*

Cybium commerson (Lacépède).

Yokoshimasawara, totuh (Taiwan), ushisawara.

Fig. 36.

Scomber commerson, Lacépède, Hist. Nat. Poiss., II, 600, Pl. 20, Fig. 1, 1800.
Cybium commersonii, Cuvier, Regne Anim.; Rüppel, Atl. Fische, 94, Taf. 25, Fig. 1,
    1828 ; Cuv. & Val , Hist. Nat. Poiss., VIII, 165, 1831 ; Rüppel, N. W. Fische, 41 ;
    Gunther, Cat. II, 370, 1860 ; Day, Fish. India 255, Pl. LVI, Fig. 5, 1875 78 ;
    Klunzinger, Fisch. Roth. Meer, 112, 1884.
Cybium multifasciatum, Kishinoye, Sui. Gak. Ho. I, 9, Pl. I, Fig. 3, 1915.

D. 17, 15, 9.   A. 14, 9.   Gill-rakers 1 + 2.   Vert. 20 + 24.

Body elongated, fusiform, highest near the middle part, that is at the origin of the second dorsal, and nearly rounded in cross-section.   Snout

long. Minute scales are found all over the body. Lateral line undulating, making a marked curve behind the second dorsal. Scales on the lateral line are about 230 in number. Teeth in jaws short, triangular, nearly straight, much compressed, and very minutely serrated as in *Acanthocybium*. There are about 30 in the upper and 20 in the lower jaw. Teeth on the vomer and palatines are very minute, granular and indistinct, as KLUNZINGER rightly remarked "viele rauhe Plättchen." The intestine is very long, and bent four times. Air-bladder present. Lateral keel of the caudal peduncle rather low. Back greyish blue, and the belly silvery. On side of the body about fifty transverse bands which fade gradually towards the ventral median line. In young specimens these bands are represented as elongated dots on the sides and very few in number. With the growth of the fish, these markings elongate and increase in number. Mouth cavity nearly colourless.

The flesh is said to be fatty but firm, and is superior in taste to that of our common seerfish, *Cybium niphonium*. Spawning season seems to be in spring, when they visit the coast of Taiwan in schools. In July immature fishes of about ten cm. are found in Taiwan, and immature fishes of about twenty cm. in the markets of south China in autumn.

The first specimen caught in Japan proper and identified as belonging to this species was found by Mr. YOZO NAKAJIMA, at the northern coast of Yamaguchi-ken, and was sent to me for identification, in Dec. 1914. The fish measured 126 cm in the total length, and 20 kg in weight. According to Mr. NAKAJIMA this species is caught on the Japan Sea coast of Yamaguchi-ken from October to January, in fixed seines or gill-nets for *Seriola quinque-radiata*. Only two or three are caught in a haul. Here they seem never to come to a ground shallower than 30 metres.

This species is abundant on the west coast of Taiwan in winter and spring. It is very widely distributed in the Indo-Pacific region, being known in New Guinea, East India, India, Red Sea, Cape of Good Hope, Samoa, and Australia. Mr. K. MIYAGAMI collected many immature specimens in autumn in southern China, and a few stragglers are caught on both sides of the Strait of Chosen in autumn and winter. This species is remarkable for migrating to the north in cold months and to the south in warm months. Large schools are hauled in Taiwan in a seine or caught with troll-lines, set nets, or drift

nets. Caught abundantly on a calm day after a strong gale.

Cybium chinense Schlegel.

Inusawara, awsawara, hasawara, hoteisawara, kusunochi, okisawara,

uke, ushisawara.

Figs. 34, 40.

? *Scomber sinensis*, Lacépède, Hist. Nat. Poiss. III, 23, 1802

? *Cybium chinense*, Cuv. & Val., VIII, 180, 1831.

Cybium chinense, Schlegel, Fauna Japon., Poiss, 100, Tab. 53, Fig. 1, 1850; Kishinouye, Sui.
Gak. Ho, I, 11, Pl. 1, Fig. 5. 1915

Scomberomorus chinensis, Kishinouye, Zool. Mag. Tokyo, XX, 1, Pl. 2, Fig. 1, 1908.

D. 16, 15, 8. A. 16, 7. Gill-rakers $2+9$. Vert. $18+22$.

Body elongated, laterally compressed, and becomes deep rather suddenly behind the nape in some forms, probably the male. Head large, pointed, and concave in the dorsal outline. Snout long. Teeth in jaws lanceolate, trenchant, and curved inward, about 20 in the upper and about 15 in the lower jaw. Villiform teeth on the vomer, palatines, and the tongue. First dorsal rather low, becomes almost invisible in the posterior part, being hidden in the groove. Caudal very large and powerful. Pectorals remarkably large and rounded. The lateral line has a marked curve under the posterior part of the first dorsal, and is undulating in the caudal portion, where the lateral line is found below the lateral median line. The intestine is bent a little near the middle point. Abdominal cavity rather high.

Back greenish blue, belly silvery, and fins mostly blackish. Ventrals and the anal are blackish at the margin, but the anal finlets are quite colourless. Iris is silvery or washed with light brown.

This species attains a big size, being the largest one among our scerfishes. A fish of 2 m in length, and 80 kg in weight is recorded. Too fat, and more or less inferior in quality. Not sought after with a special fishing apparatus. Some-times unintentionally caught in nets for other fishes. Rather abundant on the southern coast of Chosen, two or three dozens of this species being often caught on an autumn day, in a pouna-net erected at a depth of about 20 m ; and in the fish-market of Fusan gigantic forms of this species attract visitors' eyes.

On the Pacific coast the northern limit of the distribution of this species is found in the east off Chiba-ken, and in the Japan Sea off Akita-ken.

Chiefly found on the coast of the southwestern part of our country, in Kyushyu and Chosen. More or less abundant in the Japan Sea. Not found in the clear warm water of the Kuroshiwo. It is said that this species is often found at a spot where two currents of water meet in violent commotion, and this species seems to have habits similar to spearfishes.

Whether *Scomber sinense* LACÉPÈDE and *Cybium chinense* CUVIER are synonyms of this species is not quite certain, as their descriptions being founded on a Chinese picture are very poor; but so far as we know there is no other species in the oriental waters than the present one which has the lateral line bent beneath the first dorsal. Therefore the Chinese picture on which these species were founded will probably represent this species.

Cybium guttatum Cuv. & Val.

Kahpah.

Fig. 61.

? *Scomber guttatus*, Bloch, Schneider, 23, Taf. 5, 1801.

Cybium guttatum, Cuv. & Val., Hist. Nat. Poiss. VIII, 173, 1831; Günther, Cat. II, 371, 1860; Day, Fish, India, 255, Pl. LV, Fig. 1, Pl. LVI, Fig. 4; Cantor, Malay Fish., 111, 1849; Kishinouye, Sui. Gak. Ho, I, 379, 1916.

D. 16, 19 or 20, 8 or 9. A. 21, 8. Gill-rakers 2+8. Vert. 21+30.

Body elongated, laterally compressed, and nearly naked outside of the corselet. Caudal portion long and broad. Second dorsal, anal, and the caudal well developed, but the pectorals are small. Teeth in jaws sharp, about 17, minute teeth on the vomer, palatines, and the tongue. Lateral line is nearly straight with a slight bend, a little before the caudal keel. Numerous short branches are found in the anterior half. They are oblique, closely set, and are longer towards the nape, diverging backward. The scales on the lateral line are about 170.

The right lobe of the liver is large, while the middle lobe is short and narrow. Intestine is slender with a loop at the middle. The inner wall of the stomach has about twenty longitudinal folds, half the number of which are smaller and alternate with the larger. Pylorus descending, stump at the distal end, and communicates with the duodenum by a very narrow opening. The duodenum is nearly as long as the pylorus, wide at the fore end, with one anterior pyloric canal and another large posterior canal. Air-bladder wanting.

Body silvery greyish with several rows of dark spots on the side. Two dorsals, dorsal finlets, and the caudal are black. Anal and anal finlets are colourless.

Specimens examined measure about 60 cm.

Widely distributed in the Indo-Pacific region and also in Australian waters. Rather abundant in Taiwan.

Cybium koreanum Kishinouye.

Hirasawara.

Fig. 35.

Cybium koreanum, Kishinouye, Sui. Gak. Ho, I, 11, Pl. 1, Fig. 6, 1915.

D. 14, 19–21, 9.   A. 18–21, 7.   Gill-rakers 3+10.   Vert. 20+26.

Body very deep, deeper than the length of the head, and broadest at the line connecting the origin of the second dorsal and that of the anal. Snout short. Small scales are found in the corselet, lateral line, and round the base of the fins. They are, however, chiefly concealed under the skin, so that the body seems to be entirely naked. Teeth in jaws sharp, elongated, 16–19 in the upper, and 13–15 in the lower jaw. Villous teeth on the vomer, palatines, and the tongue. Two gill-rakers are found on the second branchial arch. The lateral line runs nearly parallel to the dorsal outline of the body, with slight undulations. Many branches on both sides of the anterior half of the lateral line are quite similar to those found in *C. guttatum*. The ventrals are very small, but the other fins are well developed, especially the second dorsal, anal, and caudal. Intestine very long, bent more than four times. Short blind process at the end of the slender pylorus. Air-bladder wanting. Abdominal cavity very low, compared with that of other scerfishes. The inner wall of the stomach has about 15 longitudinal folds. Four pyloric tubes from the duodenum, of which the second is the longest.

Occipital crest very high, gradually ascending behind. Hyoid bones, clavicle, and hypocoracoid very broad. One auxiliary intermuscular bone in the occipital region. In some caudal vertebrae we find a lateral median groove on each side, so that their cross-section is more or less octo-radiate.

The whole body shines brilliantly with a metallic lustre. The back is greyish blue, and the belly silvery. There are three or more longitudinal rows

of small greyish spots along the lateral median line. Fins blackish, ventrals and anal finlets excepted.

It is remarkable that this fish spawns at the mouth of Daidōkō, near Chinnanpo in July, and the immature fish is caught in stow nets near the port, in August and September. Grows to a length of more than one and a half metres, and about fifteen kg in weight. Matures when the fish is about 2.25 kg in weight and 75 cm in length. At Chinnanpo the water is turbid, of a brownish colour, and in warm seasons its density at 15° C is 1.0126—1.0164 near the surface, and 1.0466—1.0482 near the bottom.

So far as we know the distribution of this species is limited to the west and south coasts of Chosen.

Caught in summer and autumn with drift nets or in pound-nets. The fishery of this fish in Daidōkō was begun by Japanese fishermen since 1917.

It feeds on sardines, anchovies and shrimps.

Very nice food fish; but becomes inferior in the spawning season.

Cybium niphonium Schlegel.

Sawara, sagoshi.

Figs. 6, 9, 32, 41.

? *Cybium niphonium*, Cuv. & Val., Hist. Nat. Poiss., VIII, 180, 1831.
Cybium niphonium, Schlegel, Fauna Japon. Poiss., 101, Tab. 53, Fig. 2; Kishinouye, Sui. Gak. Ho, I, 19, Pl. 1, Fig. 4, 1915.
Scomberomorus niphonius, Tanaka, Fish Japan, I—X, 151, Pls. 42, 44, 1912.

D. 19, 15, 9.   A. 15–17, 8.   Gill-rakers $3+9$–10.   Vert. $22+28$.

Body slender, elongated, and compressed, covered with such minute scales that they are not stripped before cooking. Corselet indistinct. First dorsal very long, and its dorsal outline is of very slight slope. Pectoral concave at the inferior posterior margin. Lateral line undulating, and has a marked curve below the second dorsal. Many small branch-canals are found on both sides of the lateral line, but they are not so distinct as in *C. guttatum* and *C. koreanum*. Teeth in jaws lanceolate, curved, and trenchant, about 25 in the upper and about 20 in the lower jaw. They are a little smaller than those of other species. Villous teeth on the vomer and palatines, but none on the tongue. Only one gill-raker on the second gill-arch.

The right lobe of the liver is longer than the others. The inner wall of the stomach is provided with about 12 longitudinal folds. Intestine slender, straight, without any loop. No blind sac to the pylorus. Duodenum saccular, more or less flattened, and wide. There are about six pyloric tubes. The tube opening just behind the pylorus is longest. No air-bladder.

The whole body shines with a metallic lustre. The back is light greyish blue, washed with green, and the belly silvery. In a living fish we observe a purplish shade. Seven or more longitudinal rows of greyish spots are found on each side of the body. Some anterior spots in the median row are often connected together. The male fish is said to be darker in colour than the female. Pectorals, two dorsals, and the caudal are blackish. Ventrals and the anal are nearly colourless. Immature fish of about 7 cm lacks markings. They are broader, compressed and have a longer head than the adult.

Grows to a length of about 1 m. and 4.5 kg in weight. A fish under one half metre long, and about one kg in weight is generally immature, and is called "sagoshi." A fish under about two kg in weight is called "koza-wara" by fish-mongers.

This species is a good and valuable food-fish, caught all the year round, and especially abundant in spring, when the fish spawns. Spawning season is from April to May. The ripe ovum is very large, about 1.5 mm in diameter. The larval fish is remarkable in having a large head with well developed strong teeth in jaws. Immature fish of about 3 cm are found in April and May. They grow to 10—20 cm in winter. Those immature fish are found in shallow waters and are caught in drag seines for sardine.

Ovarian ova do not mature at the same time; but here and there some ova become large and transparent, and assemble to the central cavity to be discharged.

Though wanting in the air-bladder this species has a rather wide range of vertical distribution, swimming near the surface of water in warm seasons, and descending to the deeper layer of waters in cold seasons. Geographically this species is widely and abundantly distributed in coastal waters (10—20° C, 1.022—1.024 in density) of our empire;—Hondo, Shikoku, Kyushyu, and Chosen, and also in waters of northern China. Most abundant in the middle part of the empire, especially on the coast of the Inland Sea,

but becoming more scarce in the northern and southern parts. A few stragglers are sometimes found on the coast of Hokkaido. This species enters the Inland Sea and bays in the spawning season. It becomes very lean after spawning; but recovers its fattiness already in autumn. In summer and autumn the fish is often found near the surface, it leaps out of the water, but in the cold months it lives near the bottom. At the flood-tide the fish is more active and is said to pursue small fish violently, often tearing drift nets with force. Thus fishermen of some villages of Nagasaki-ken are said to use the drift net for this fish at the time of the ebb-tide only.

A fishery expert in Kagawa-ken estimated the number of ova spawned from an adult fish in a season to be 550,000—870,000.

In the migration to the Inland Sea the male fish is more numerous at the beginning of the season; but the female fish predominates near the close of the season. At this time the female fish may easily be distinguished from the male by the thick and swollen abdomen.

Caught with troll- or hand-lines, set-nets, drift nets, seines, pound-nets etc. Long lines are seldom used, as the fish are not easily induced by dead or inactive baits. When empounded in pound nets at night the fish seem to try to escape through the meshes at the bottom.

In the Inland Sea trollers expect good catches within the two hours before and after the ebb-tide, especially at dawn. In this sea the fish feeds principally on the sand-eel.

A jaw bone of this fish was found in a shell-mound in Chiba-ken, which proves that the prehistoric people in our islands also caught this fish. However the fishery of this fish seems to have developed very slowly. The name is not mentioned in very old literature, such as the "Yengishiki" and the "Manyoshyu", though many other common kinds of fish are enumerated.

Late in November, 1902, a fisherman of Niihama, Yehime-ken, caught about fifty adult sawara with drift-nets. This untimely catch caused much astonishment. Generally adult sawara leave the Inland Sea soon after spawning, latest at the end of June.

From a recent inquiry of the Experimental Fishery Station of Kagawa-ken, it became clear that this species comes to the Inland Sea again in autumn, though not so abundant as in spring. However, it is thought

that the fishery in autumn in the Inland Sea will be remunerable to open-boat drifters.

Genus **Sarda** Cuvier.

Sarda, Cuvier, 1829; Jordan & Evermann, 1895.
Pelamys, Cuv. & Val., 1831; Günther, 1860.

Body elongate, but rather short and compressed in young specimens. Scales minute, and a small corselet more or less distinct. The caudal keel is thick and naked. Teeth in both jaws are large, compressed, and strongly curved inward, but not trenchant. Near the anterior end of the lower jaw, the row of teeth is bent inwards and approaches the symphysis. Vomer is toothless, but a single row of rather strong and curved teeth on the palatines. Tongue also toothless. Many dark, longitudinal, more or less oblique stripes are found in the dorsal part of the body. Vertebrae of the caudal peduncle have lateral keels. Voracious fish of rather small size in subtropical and tropical waters of both Pacific and Atlantic Ocean. Pelagic.

Sarda orientalis (Schlegel).

Hagatsuwo, hohzan, kitsunegatsuwo, sabagatsuwo, shimagatsuwo, sujigatsuwo, tohzan, etc.

Figs. 11, 17, 33, 42.

Pelamys orientalis, Schlegel, Fauna Japon. Poiss., 99, Tab. 52, 1850; Günther, Cat. Brit. Mus. II, 368, 1860.
Sarda chilensis var. orientalis, Stendachner & Döderlein, Beitr. z. Kennt. d. Fisch. Japan., III, 11, 1883.
Sarda orientalis, Kishinouye, Sui. Gak. Ho, I, 12, Pl. 1, Fig. 7, 1915.

D. 19, 15, 7–8.   A. 15, 5–6.   Gill-rakers $4+9$.   Vert. $25+20$.

Body elongated fusiform in adult specimens, but rather short and compressed in young specimens. Mouth wide, maxillary reaching beyond the orbit, with large curved and compressed teeth. Teeth in jaws are more or less unequal in size. About 16 in the upper, and 10–13 in the lower jaw. Groove in the skin from the corner of the mouth is present, as in the tunnies. Posterior nostril is a mere slit. Scales minute. Lateral line undulating slightly, and has a peculiar, wave-like bend over the pectoral fin.

Stomach long, with more than twenty longitudinal folds. Intestine

nearly straight, boundary of the rectum indistinct. Pylorus descending with a few longitudinal folds inside, and rather narrow.

Liver consists of three slender lobes, of which the two lateral lobes are very long and nearly equal in length, while the middle one is short.

Myotomes are strongly folded, so that in the cross-section of the lateral muscle we count nearly as many rings as in the same of tunnies. The median wedge-shaped portion of the lateral muscle is reddish, and the red portion becomes thicker towards the tail. On the surface of the last myotome we cannot find a tendon.

Skeleton porous and rather weak, and much resembling to the type of the Cybiidae. The vertebrae of the caudal peduncle are provided with lateral keels, each of which is divided into two, anterior and posterior portions. Two auxiliary intermuscular bones are found on the exoccipital,—one on the dorsal wall of the foramen magnum, the other a little forward. At the dorsal part of the clavicle the anterior pointed process is widely separated from the posterior lamellar part.

Grows to a length of about 80 cm and to a weight of 1.5–3.0 kg.

Flesh is rather soft and inferior in quality. Generally this species is not specially sought after, except in Kyushyu, but is caught as an adjunct in fisheries of the mackerel, bonitos, sends, etc. It is said that in Kyushyu a few pound-nets are specially built for the capture of this species.

This species lives rather near the surface of the coastal waters, and sometimes makes large shoals. It bites eagerly on a bait, natural or artificial, hence it is easily caught with trolling lines.

Found in the southern parts of our waters, both on the Pacific as well as on the Japan Sea coast, especially abundant in Kyushyu. Many years ago, an immature example was caught in a drag-seine on the Pacific coast of Aomori-ken. The Hawaiian species of *Sarda* seems to be the same as the Japanese species, but the Californian seems to belong to the Chilian species.

Many authors have confounded this species with an allied species from the Pacific coast of South America; but the difference between them is quite evident. As SCHLEGEL rightly remarked, the pectorals are smaller in *Sarda orientalis*, and not only these fins but the other fins are also smaller. Moreover the number of gill-rakers is $9+17$ in *Sarda chilensis*, and the number of

vertebrae is $22+22$. The dark stripes in the back are fewer, and more oblique in *S. chilensis*, and much wider apart than in *S. orientalis*.

Genus **Gymnosarda** Gill.

Gymnosarda, Gill, 1862.

Body long, fusiform with a large head. Mouth large, but the maxillary does not reach beyond the orbit. Eyes large. Scales in the corselet elongated, and concealed under the skin. Outside of the corselet and the base of the fins the skin is entirely naked. Lateral line undulating. Teeth in jaws large, curved, and nearly conical. Villous teeth on the tongue and palatines, but the vomer is toothless. Caudal portion very slender with a well developed keel on each side.

First vertebra is very short. Cross-section of caudal vertebrae is more or less cruciate, but the lower end of the perpendicular limb is always bipartite. Anterior precaudal vertebrae with three ventral grooves. In external appearance fishes of this genus are closely related to tunnies.

Pelagic fish of voracious habit, and of somewhat large size in the littoral waters of the tropical region, chiefly Indo-Pacific; but a species is recorded from European waters,—the Mediterranean and the North Sea. In spite of great differences in external characters, as well as in the internal anatomy, many authors confounded this genus with the genera *Katsuwonus* and *Euthynnus* of the Katsuwonidae.

Gymnosarda nuda (Günther).

Isomaguro (Ogasawara Is.), tokakin (Ryukyu Is.).

Thynnus (Pelamys) unicolor, Rüppel, N. W. Fisch., 40, Taf. 12, Fig. 1, 1838.
Pelamys nuda, Günther, Cat. Brit. Mus. II, 368, 1860; Kunzinger, Fisch. d. Roth. Meer., 110, 1884.
Gymnosarda nuda, Kishinouye, Sui. Gak. Ho, I, 13, Pl. 1, Fig. 8, 1915.

D. 14, 13, 7. A. 12, 6. Gill-rakers $2+10$. Vert. $19+19$.

Body fusiform, entirely naked outside of the small corselet. Head comparatively large and the caudal peduncle very slender. As the scales of the corselet are concealed under the skin, small wrinkles are found around the pectorals, and several longitudinal furrows on both sides of the dorsals. Lower jaw broad. Teeth in the upper jaw are 18-23, and in the lower jaw 10-16.

Lateral line runs parallel to the dorsal outline of the body, nearly to the twelfth spine of the first dorsal. Below the spine the line is bent downward. Behind the vertical from the first dorsal finlet, a few undulations in the line. Scales of the lateral line are also concealed under the skin, and on both sides of the pored scales we find two or three rows of minute scales. The lateral keel of the caudal portion is also covered with minute, elongated scales. The third spine of the first dorsal is longest and thickest, though RÜPPEL reports that in his specimens the second spine is the longest. Air-bladder large and thick-walled, though RÜPPEL denies its presence. Pyloric coeca form a conspicuous mass in the abdominal cavity as in other forms of the Cybiidae, so that it is strange that they escaped the eyes of RÜPPEL, but the fact that the mass of the coeca is enormously developed deceived the naturalist, probably the mass was taken as a part of the liver or other organs, as KLUNZINGER (49) remarked in his work.

Skeleton firm and strong. The number of vertebrae is very small, compared to that of the species of *Cybium*. Skull flat and broad. Anterior half of the frontals is provided with many oblique ridges, and covered directly with the skin. Posterior margin of the preopercle is a little undulating. Dorsal anterior margin of the opercle is slightly concave. Inner limb of the subopercle is large. First vertebra is very thin and its neural process is free from the centrum. Anterior precaudal vertebrae want the parapophyses, and the lateral keel of the caudal peduncle is narrower than the diameter of the centrum. The last haemal process is coalesced to the fan-shaped hypural bone. Cross-section of vertebrae is not exactly cruciate in most of them, but more or less sex-radiate. Haemal arch is formed from the eleventh vertebra, and haemal spines of some length are found in precaudal vertebrae. Inter-muscular bones are very numerous, being found to the 29th vertebra.

Colour is said to be dark bluish to violaceous at the back, and greyish white at the belly. Top of the head and the anterior end of the lower jaw are greyish. Fins are black or greyish, leaving the tip of the second dorsal and anal colourless.

It is told that the fish attains the big size of about 240 cm with a weight of 80 kg; but fishes now commonly caught at the Ogasawara Islands are 100–150 cm in length, and 20–30 kg in weight.

Known from the tropical regions of Indo-Pacific waters. Caught with harpoons, hand-lines, and trolling lines at the Ogasawara and Ryukyu Islands

Voracious fish, resorting to the rocky bottom of coastal waters in small schools of tens or scores, devouring *Caesio, Decapterus*, etc. Not found in off-shore waters. Caught at grounds about 20–200 m off, with hooks dressed with live baits. Bites hooks readily in the twilight. When there is no tidal current the fish is easier caught. A better catch is expected in the spawning season, May and June, though it is caught all the year round. Some condemn the flesh of this fish as soft and unsavoury, but others commend it as delicious. This difference of opinion is perhaps due to the difference of season in which the fish was tasted. KLUNZINGER (49) says "selten einzeln, in hohen Meeren, meist tief, kommt selten herauf. Frisst als Lockspeise Clupeiden und kleine Sphyränen. Fleisch geschätzt."
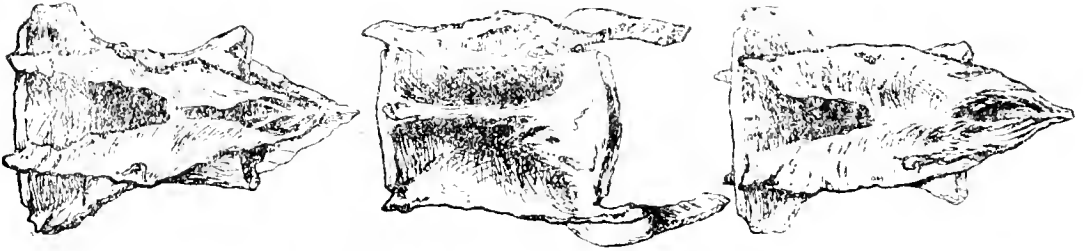
Fig. Y. A caudal vertebra from a shell-mound of Ogido. 7 9 nat size. From left, dorsal, lateral and ventral views.

Recently Mr. AKIRA MATSUMURA of the Anthropological Institute of our University sent me for identification a large vertebra obtained from a shell-mound in Ryukyu. The vertebra is closely allied to the 31st vertebra of the present species, but not exactly, differing in the shape of the lateral keels, and the neural and haemal grooves.

Order PLECOSTEI Kishinouye.

Plecostei. Kishinouye, 1917.
Thannidae. Kishinouye, 1915.
Thunninae. Starks, 1910.

Group of teleostomatous fish, having a cutaneous vascular system, con-nected with the vascular plexus developed as sheets in the lateral muscle.

Portions of the lateral muscle surrounded by these sheets of the vascular plexus are situated on both sides of the vertebral column, and are dark red, nearly black in colour. Another peculiar vascular plexus is developed on the inner side of the liver or in the haemal canal. Moreover the circulation of blood in the liver is especially well developed.

Thus this group of fish is distinctly defined from the other forms of the Teleostomi, and comprises the most highly specialized forms of fishes. There is no doubt that they are descendants from the Acanthopterygii, among which they should have been classified. They are most closely allied to the genera *Sarda* and *Gymnosarda* of the Cybiidae.

The body is well adapted for swift locomotion, being plump, pointed at both ends, and smooth at the surface. Caudal peduncle very slender, but with broad lateral keels. Head triangular, nearly flat at the top. Snout shorter and the mouth smaller than in the Cybiidae, the upper jaw scarcely reaching the vertical from the middle of the eye. The posterior part of the external margin of the upper jaw is not straight, but bent downward, due to the over-lapping of the maxillary over the premaxillary. Posterior end of the upper jaw is straight, due to the form of the supplementary bone. The anterior nostril is a mere point, and the posterior nostril a transverse slit. Scales large and thick in the corselet, and those behind the eyes are thick and elongated. Scales are ctenoid at the margin but smooth at the surface. Opercular region is entirely naked. Corselet is covered with a thick membrane of strong connective tissue, to protect the thick part of the peculiar cutaneous vascular system.

Fins are well developed with thick spines and strong fin-rays. In the first dorsal the first spine is not inferior in size and thickness to any succeeding spines, and the posterior side of the dorsal outline of the fin is concave. The caudal fin is firm and very widely forked, more or less lunate in shape.

Gill-rakers are long and fine, and are developed on both sides of branchial arches. Abdominal cavity is narrow and depressed, as the ventral processes of the precaudal vertebrae are well developed, consequently the hypaxial portion of the lateral muscle in the precaudal portion is very thick (Figs. 18, 19). Portions of the lateral muscle on both sides of the vertebral column are coloured dark red or blackish. These portions are called " chiai " in Japanese, and each dark red portion is thick at the anterior end, tapering gradually

towards the posterior end. The chiai portion is soft and poor in taste, and contains about seven to fifteen times as much blood as the other portion, estimating from the colour.

Pylorus short, descending, runs along the inferior side of the stomach. Duodenum receives at the posterior side five or six dendritic canals carrying the tufts of pyloric coeca, and in bonitos two short tubes on the anterior side as well. These dendritic tubes greatly vary in length. Each terminal branch of these tubes ends with a tuft of coecal outgrowths of nearly equal size, and yellowish in colour. Each group of these tufts is covered with a membrane, and the whole mass of these tubes is covered with a thick membrane to form a compact mass. In these tubes we find a half digested mass of food, but in the yellow tufts we have not found it yet.

Myotomes at the surface of the body are bent with acute angles at 5 points, so that we find more than ten concentric circles in the cross-section of the lateral muscle in each quadrant. There are three myotomes in the cephalic region, and generally we find an auxiliary intermuscler bone between the last two. Myotomes in the caudal peduncle seem to have been reduced in number. Moreover the terminal tendon of these myotomes are well developed, and may be distinctly seen at the outer surface of the muscle, when we remove the skin.

The vascular system is very complicated and variable in different members of the group. Besides the cutaneous vascular system we find many peculiarities. It is remarkable that in the ancestral forms of tunnies the posterior cardinal vein does not pour directly into Cuvier's duct. In these tunnies the principal veins uniting with the Cuvierian ducts are two large cutaneous veins carrying blood from the dark red portion of the lateral muscle, and the anterior jugular veins. The posterior cardinal vein is insignificant and communicates with lateral commissures at the caudal peduncle to the cutaneous veins mentioned above. In these forms hepatic portal veins form a massive plexus on the axial side of each lobe of the liver. In more advanced forms, however, the posterior cardinal vein is well developed and united with the right Cuvierian duct. In these forms the venules flowing downwards from the dark red portions collect to the comparatively spacious haemal canal, and there they are divided into many short parallel transverse canals, which fill up the canal entirely, forming a solid mass in it. In still more modified

bonitos, the cutaneous veins do not unite directly with the Cuvierian duct, but form hepatic portal veins. In bonitos the vascular plexus is also found in the haemal canal. Blood vessels in the air-bladder belong to the visceral vascular system.

In primitive tunnies the kidneys are more or less ring-shaped, just behind the head, and around the pharyngeal muscles. In the other tunnies the kidneys are produced more or less behind, and in bonitos they are elongated nearly to the end of the abdominal cavity. Posterior portions of the kidneys lie chiefly on the roof of the abdominal cavity but, in the haemal canal too we find a continuous or sometimes small discontinuous masses of a kidney-like brownish substance with minute black spots.

Skeleton firm, solid, and comparatively light. Skull firmly consolidated. The dorsal surface of the skull is entirely covered with the lateral muscle and there we find paired non-ossified portions, except in the genus *Auxis*. On the ventral side of the skull we find many deep grooves for the insertion of opercular muscles. The posterior end of the parasphenoid is more or less tubular. Subcranial cavity is very high. Lower piece of the postclavicle is not flat, the broad proximal part making nearly a right angle with the narrow distal part, and these two parts are in two different planes. The distal part is very short in many cases. Clavicular ligament is inserted in the first vertebra not to the skull.

Vertebrae are compact and rich in grooves and ridges, so that they are light and firm. The total number of vertebrae is always 39, except in the genus *Katsuwonus* which has 41. They differ from each other in form, processes, etc, in different parts of the vertebral column. Neural and haemal processes are more or less laterally compressed. The first neural process is remarkably feeble.

Fishes of this order seem to have their own temperature, more or less higher than the temperature of the water in which they live. They are voracious, pelagic fish, swimming very fast, and feeding on small fish, calamaries, and medium sized plankton. Found in temperate and tropical seas. They spawn in off-shore grounds and grow there. They are very energetic and powerful, therefore specially long and strong implements are required for catching them.

Key to the families of the order Plecostei.

Body wholly covered with scales, second dorsal and anal high, vertebrae 18+21,
    transverse process present, 1st vertebra short, anchylosed to the skull, alis-
    phenoids meet at the ventral median line, air-bladder generally present.....*Thunnidae*.
Body naked outside of the corselet, second dorsal lower than the first,
    vertebrae generally 20+19, some intermuscular bones are divided into two,
    distal and proximal, epihaemal spine developed between the centrum and
    the haemal arch in most vertebrae, network of haemal processes well
    developed, air-bladder wanting .... *Katsuwonidae*

Family THUNNIDAE Kishinouye.

Thunnidae, Kishinouye, 1918.

Body plump, wholly covered with scales, which differ in size and form in
different parts of the body. Corselet well developed, but its boundary is not
distinct. The lateral line has a peculiar curve above the pectorals. Teeth
rather feeble. Single series of small conical teeth in both jaws. They are sharp
and curve inward. Villiform teeth on the vomer, palatines, and pterygoids. Many
dentigerous calcareous plates are found on the palate. The denticles on these plates
are quite similar to those found on the vomer, palatines and pterygoids. Thus
the roof of the mouth-cavity is quite rough, contrary to the nearly smooth roof in
the Katsuwonidae. Three lobes of the liver subequal. Intestine rather long, with
three folds. Pyloric tubes developed only on the posterior convex side of the
duodenum. Pyloric coeca heteroclitic, irregular in size. Those found at the
distal end being longer and thicker than those at the proximal part. This
heterochrony is more marked in primitive forms. Rectum short, it has nearly
the same diameter as the preceding part of the intestine. Air-bladder present,
except in *Neothunnus rarus*.

Cutaneous blood-vessels above and below the lateral median line are united
both at the anterior and posterior ends, and are connected by short horizontal
vessels with the chief blood-vessels in the haemal canal at the caudal peduncle.
The cutaneous veins are large and unite with the Cuvierian ducts directly or with
the cardinal vein. Each of the paired cutaneous arteries arises just behind the
pharyngeal muscles or somewhat behind it, runs backwards and downwards
behind the root of either the third or fifth rib, and is divided into two nearly
parallel branches, a little before it comes to the surface of the muscle, between
two consecutive intermuscular bones. The dark red portion of the lateral

muscle is rather narrow, and meets the axial skeleton with a narrow neck or root in the hypaxial portion only.

Ligament in a deep median groove between the anterior end of the frontals is attached to the skin, anterior to the median foramen of the skull. This ligament is a characteristic of this family.

The transverse process of some precaudal vertebrae is broad, well developed. The first vertebra is greatly reduced in height and firmly anchylosed to the skull. Inferior foramen is small, and is found in the caudal vertebrae only. Number of vertebrae is constant, 39 in total, of which 18 are precaudal, and 21 caudal. The haemal canal is closed in the tenth or eleventh vertebra, i. e. near the middle of the precaudal region. Alisphenoids meet at the ventral median line. Anterior precaudal vertebrae, are broader than high. Roof of the mouth cavity is covered with numerous plates covered with villous teeth.

Many systematists put too much weight on the length of the pectorals, but it has little value in the classification.

Key to the genera of Thunnidae.

Cutaneous blood-vessels pass through the myotome of the fifth vertebra, surface
    of the liver striated with fine venules..*Thunnus.*
Cutaneous blood-vessels pass through the myotome of the seventh vertebra,
    surface of the liver not finely striated with venules.
        Posterior cardinal vein is not continuous with the Cuvierian ducts.
            Vascular plexus on the inner side of the liver. ....*Parathunnus.*
        Posterior cardinal vein is continuous with the Cuvierian ducts, vascular
            plexus in the haemal canal....... ....*Neothunnus.*

Genus **Thunnus** South.

Thunnus South, 1845.
Thynnus, Cuvier, 1817 ; Günther, 1860.
Orcynus, Cuvier, 1817.
Germo, Jordan, 1888.
Albacora, Jordan, 1889.

Body plump, robust. The first haemal canal is closed in the tenth vertebra. Anterior haemal arches of the precaudal region are turned forward and narrow. Right side of the stomach receives an artery from the downward branch of the coeliaco-mesenteric artery. Two large branches of the coeliaco-mesenteric artery send their blood to the liver, and they are finely divided into plexus on the inner side of the liver. These plexus reunite into several arteries to

the stomach, spleen, and intestine. The hepatic portal veins running along
these arteries are also subdivided into plexus before entering the liver. The
oesophageal artery is not well developed, and the coeliac arteries are branched
from hepatic arteries. Cutaneous arteries branch from the dorsal aorta below
the fifth vertebra and just behind the pharyngeal muscles. Arterial and
venous plexus on the axial side of the liver.

Round the spots of emergence of the hepatic veins the liver consists of
only, a thin sheet of venules the substance of the liver not being found in
these spots. Thus the liver is thickest midway between the root of the
hepatic veins and the attenuated margin of the liver. Vascular plexus on the
axial side of the liver are also situated at the thin portions, and are surrounded
by thick masses of the liver. Roof of the abdominal cavity is convex, at the
anterior part. External wall of the air-bladder is uniformly thin. Kidneys
ring-shaped.

<div align="center">Key to the Japanese species of the genus Thunnus</div>

Pectorals very long, reaching to the second dorsal finlet, markings in the belly,
  when present, longitudinally anastomosing. ....*Th. germo*
Pectorals not reaching to the vertical of the origin of the second dorsal,
  markings in the belly transverse, and constantly present. ....*Th. orientalis.*

Thunnus germo (Lacépède).

<div align="center">Tomboshibi, binchoh, binnaga, kantaro.</div>

<div align="center">Figs. 20, 46, 52.</div>

Scomber germo, Lacépède, Hist. Nat. Poiss. II, 598, III, 1, 1802.
Thynnus pacificus, Cuv. & Val, Hist Nat. Poiss. VIII, 133, 1831 ; Günther, Cat. Brit
    Mus. II, 366, 1860.
Germo germo, Jordan & Seale, Bull. Bur. Fish. XXV, 175, 1905.
Thunnus alalunga ?, Kishinouye, Sui. Gak. Ho, I, 18, Pl. 1, Fig. 10, 1915.

D. 14, 14, 8. A 14, 8. Gill-rakers 9+18-19. Scales ca. 210.

Body rather slender, head and eyes comparatively large, caudal portion
short. Scales rather large, about 210 in the lateral line. Pectorals sabre-
shaped, very long, reaching to the first anal finlet. Lower margin of these
fins is a little concave at the proximal part. Height of the second dorsal is
equal to or a little shorter than that of the first dorsal.

The roof of the abdominal cavity is remarkably convex. So the cavity is

very narrow and the flesh very rich in amount. Three lobes of the liver are connected with each other by very narrow portions, and the lateral lobes are divided into many lobules at the margin, as well as at the inner side. On the outer side of the liver we find very fine parallel venules, covering nearly the whole surface of the liver. On the inner side of the liver bulbous and more or less conical masses of vascular plexus of both arterioles and venules are found.

Venules to the cutaneous vein are arranged in two alternate rows, and are more numerous than the arterioles. These venules pour to the inner side of the vein. Arterioles from the cutaneous artery are arranged in one row, and on the inner side of the artery (fig. 20). Venules are very minute and numerous, forming thick sheets in the lateral muscle, before pouring into the cutaneous vein. These venules form numerous small bundles by uniting just at the root. Each of the numerous branches from the cutaneous artery is minutely divided as soon as it emerges from the main blood-vessels, and running along the venules supplies fresh blood to the dark red portion of the lateral muscle. The cutaneous artery originates just behind the pharyngeal muscle in the levels of the fifth vertebra and runs obliquely backward.

Air-bladder present, rounded at the anterior end, and its wall is rather thin. It is narrow, but long, running the whole length of the abdominal cavity. Kidneys of both sides are united to form a flat, ring-shaped body round the pharyngeal muscles. The ring-shaped kidneys are slightly prolonged backward. Ureters of both sides meet in a nearly straight line, thick at the junction. In this thick junction, we find a short longitudinal septum from the anterior wall. Posterior to this septum the ureters are joined to a median tube.

Skull rather narrow. Vertebral column more or less slender. Height of the vertebrae nearly uniform. Parapophyses well developed. Parapophyses of the ninth vertebra are almost horizontal as in the preceding vertebrae; but in the tenth vertebra the haemal arch is formed and is turned forward leaving only a little space between the centrum and the arch. In each of the following precaudal vertebrae the haemal spine is formed, and it is remarkable that it is nearly uniformly elongated. These precaudal haemal spines are remarkably longer than in other tunnies. The head of the second and third ribs is very

thick, and the distal portion of these ribs is broad, thin, and gradually narrow. The part between the head and the broad distal portion is very narrow to admit the passage of the cutaneous blood-vessels.

The colour is blackish blue in the dorsal part, with a greenish lustre near the tail. Sides and belly are silvery. In young specimens, ca 60 cm in length, we find some five or six dark, irregularly longitudinal bands, running near the ventral median line. These bands are more distinct at the caudal region, and are more or less united in the form of irregular net-work. First dorsal nearly colourless, except the dusky border. Pectorals black, ventrals and the second dorsal are dusky, but the anal is nearly colourless. The dorsal finlets are dusky, washed with yellow, while the ventral finlets are more or less dusky. Iris silvery, tinted with light blue.

This species is rather small, a germon of ca 25 kg is rather rare and large. In southern California 8 kg fishes are said to be common, a fish weighing 20 kg is considered large. In Japanese and Hawaiian waters, fishes of ca 45 kg are said to be nearly maximum and rare.

Very widely distributed in both the north and south Pacific. Caught in large quantities on the Pacific coast of Hondo, but not yet found in the Japan Sea. Found in off-shore grounds only, never approaching the coast. This species is caught in our waters till about 43° N, off the south coast of Hokkaido. In spring the germon begins to migrate northward. In this northerly migration the germon precedes the striped bonito, but follows our common tunny (*Thunnus orientalis*). In winter the germon is found in the southern part of our waters, about 34° N. Found in water of 10–25° C in temperature, and at a depth of about 80 m.

Germon or the albacore seems to have been caught in our waters since the beginning of the nineteenth century, as its name is first found in the literature of a very early period of that century. In former days the germon was caught unintentionally, while engaged in fishing for the common tunny or other kinds of fish, and was not valued, as its flesh is soft, but recently a special long-line has been used for its capture. Caught chiefly by means of long lines and drift-nets.

Flesh pinkish in colour, soft, and not good for "sashimi", hence not much esteemed in our country, but the amount of flesh is comparatively large. The

canned flesh is much esteemed as "tuna" in the United States of America.

Germon feeds on pelagic plankton, crustaceans, and small fish. I found a young germon about 30 cm in length in the stomach of a large germon, caught on January 20th, 1917 near the Ogasawara Islands, and other small ones from a yellow finned tunny and a spear-fish, caught on February 27th of the same year. Such small individuals are not caught nor found near the coast of the main island.

I cannot tell at present whether the germon of the Atlantic and the Mediterranean is the same as the Pacific germon. Specimens of the germon and the common tunny of the Mediterranean were sent to me from the Zoological Station at Naples in 1914 on a German steamer; but unfortunately the steamer was seized in the Red Sea and these specimens did not reach me. Many authors seem to have confounded this species with other species of tunnies with long pectorals.

Thunnus orientalis (Schlegel).

Kuroshibi, gotohshibi, maguro, medi (immature).

Figs. 3, 21, 43, 44, 50.

Thynnus orientalis, Schlegel, Fauna Japon. Poiss. 94, 1802.
Orcynus schlegelii, Steindachner & Döderlein, Fisch. Japon. III, 11, Taf. 3, Fig. 1, 1885.
Orcynus thynnus, Kitahara, Journ. Fish. Bur. VI, 1, Pl. 1 Fig. 1, 1897.
Thunnus schlegeli, Fujita, Otaki & Higurashi, Fish. Japan, I, 21, Pl. 1905.
Thunnus orientalis, Kishinouye, Sui. Gak. Ho, I, 17, Pl. 1, Fig. 9, 1915.

D. 13-15, 14, 8-9. A. 13-15, 7-8. Gill-rakers $12-13 + 24-26$. Scales 230.

Body plump, broad, and the caudal portion sharply tapering. Pectorals short, scarcely reaching the origin of the second dorsal, and tapering gradually towards the posterior end. The height of the second dorsal is longer than that of the first, nearly equal to that of the anal; but shorter than that of the pectorals. The lateral line has a sharp and peculiar bend over the pectorals, being bent suddenly upward and anteriorly above the origin of the fins, and then bent gradually downwards and backward again. SCHLEGEL writes that the eyes of this species seem to be larger than those of the common European tunny. In one year old fish, the eyes are larger, being contained ca 6 times in the length of the head, but in a fish of ca 2 metres they are contained more than 8 times.

The liver is nearly the same as that of the preceding species; but the margin is not much divided. Fine venules of the hepatic vein at the external surface, and big masses of vascular plexus at the internal surface are found.

Air-bladder is triangular, pointed at the posterior end. It is nearly straight, thick, and very wide at the anterior end, occupying the entire breadth of the abdominal cavity. Air-bladder of this species is however short, occupying a little more than half the length of the abdominal cavity. The external wall is uniformly thin. The inner wall is finely reticulated. At the middle of the roof of the air-bladder, there is a large round hole, which leads to an accessory conical sac, extending from the hole behind to the posterior end of the principal sac. At the anterior end of this upper accessory sac a vein is found to pour to from a segmentary vein. In immature tunnies the air-bladder is short, very narrow, and almost collapsed. The median part of the air-bladder is vaulted, and at the anterior end the cavity has two slight swellings.

Kidneys are short, and are restricted to the anterior part of the abdominal cavity. In immature forms they are ring-shaped, round the pharyngeal muscles, and terminate with a slender, short process just before the first haemal process. In adult forms, however, the posterior portion is not well developed. Ureters meet at the posterior end of the kidneys, or a little out of it. Near the level of the 7th or 8th vertebra, ureters approach each other towards the median line, and unite into a common canal.

Venules to the cutaneous vein are arranged in two rows, and those of the external side pass over the cutaneous artery, while those of the interior side run below the artery. These venules are formed from the union of many fine canals, forming the plexus round the dark red portion of the lateral muscle. Arterioles from the cutaneous artery are arranged in one row. Oesophageal artery is found but very short.

Skull broad, with convex lateral sides, and the broad and high parasphenoid. Basisphenoid thick. Alisphenoid extends downward at the median line. The anterior margin of the subopercle is more or less concave. This is quite characteristic of this species.

The back is nearly black, especially at the anterior part of the body, but the colour gradually changes to greyish blue with metallic reflections in the posterior part. Belly greyish with many colourless transverse lines and

rows of colourless dots in alternation. These lines and series of dots are twenty or more in number, and they are nearly vertical in young specimens, running through from the back to the belly; but they bend gradually backward towards the ventral median line as the fish grows. At first only colourless lines make their appearance, and afterwards series of dots are intercalated between them. Moreover the lines are also divided into dots afterwards at the belly, and they disappear gradually from the back. The dots are irregular in arrangement in the caudal region. First dorsal greyish, second dorsal greyish with yellow tip, dorsal finlets yellow, and the anal and anal finlets silvery. Pectorals nearly black, ventrals greyish. Iris golden yellow.

Flesh is dark reddish, comparatively firm, and not very oily. It is superior in quality, especially in colder months, and is much esteemed. Two year old fish are called " medi," and are much valued by epicurians. It is told that in and after the spawning season the flesh is often mottled with darker spots and is much inferior in quality. Such flesh is distinguished by the name of "azukimi", meaning red bean flesh.

This species attains a gigantic size. Mr. HIDEO SUZUKI told me that two large tunnies, each weighing about 375 kg were caught in a pound-net near Odawara in 1913. These were exceptionally large. Tunnies weighing more than 150 kg are considered pretty large in general.

This is the most common species of our tunnies, widely and abundantly distributed in our waters. It is easily distinguished from other tunnies by its small eyes, short pectorals, sharply bent lateral line, triangular air-bladder, finely striated liver, white markings in the belly, yellowish finlets without black margin, etc.

In winter this species is found in the southern part of our coast, as far south as 32° N. Not found near the Ryukyu Islands, Taiwan, nor Ogasawara Islands. In summer this tunny migrates northward as far as about 46° N. In winter the tunny fishing is actively pursued on the Pacific coasts of south and middle Japan, by means of long lines on or round deep, off-shore banks, and on the northeastern coast of Hondo by means of drift nets. In summer this tunny is caught on the Pacific coast as well as on the Japan Sea coasts of north Japan by means of pound-nets. Only a few examples are caught on the east coast of Chosen. Found in waters of 5-20° C, and

most abundant in waters of 10-15° C. Thus the optimum temperature for this species is lower than that of the other tunnies in our waters, as well as that of the common Atlantic tunny.

When albacores or spear-fishes begin to be caught, this tunny's season is nearly over. It feeds on different kinds of fish, more or less pelagic in habit, such as sardine, anchovy, flying fish, scad, sand-eel, etc.; but sometimes fishes living near the bottom are found in the stomach. Calamaries and pteropods; *Pyrosoma*; pelagic crustaceans, such as *Euphausia, Sergestes, Acanthephyra,* larvae of Brachyura and Stomatopoda, anomalous Amphipoda, etc. are also found in the stomach.

This species is closely allied to the blue-finned tuna or leaping tuna of the Californian coast, but differs from it in the colour of fins, and in the mode of ramification of canals of the cutaneous blood-vessels. A similar or the same species is said to inhabit the Hawaiian waters; but I have not yet had a chance to investigate this.

Tunnies are migratory, but they resort and seem to stay for a while at the top of deep banks, often 200 m deep. In the vicinity of such banks tunnies seem to find plenty of food. The presence of tunnies in deep water is often detected by fishermen from the behavior of sea-gulls, flying fast in a much dispersed wide circle, or from circular or oblong waveless spots, ca. 1 m in diameter, produced for a time at the surface of the sea. These spots are called " nagi ", meaning calm, waveless, and are believed by fishermen to come from the oil of fish devoured by tunnies; but as tunnies mostly engulf their prey in toto, and moreover as 1 did not observe any glittering iridescence in these spots, the explanation is not satisfactory.

Tunnies are devoured by killer-whales which are said to catch them at the nape and kill them immediately, so that they fear killers so greatly that they are frightened away several miles from the spot where these ferocious enemies are found. Thus catches made by pound-nets vary greatly according to the favourable or unfavourable proximity of killers. Sometimes tunnies leap on beaches recklessly to escape from these enemies.

In their northerly migration tunnies swim quite near the coast, and are caught in pound-nets, which are set in a depth of about twenty metres.

Small fish of about 25 cm, weighing ca. 20 g in weight are caught

with rod and line late in summer. Such immature fish are called "inoshibi" in Miyazaki-ken. Still smaller fish are called "kakinotane" in Kanagawa-ken, and "abuko" or "bintsu" in Miye-ken. These immature fishes are found in association with *Auxis*, feeding chiefly on pelagic crustaceans. These immature fish grow to a length of ca. 40 cm, weighing ca. 1 kg in winter, and in the next summer 2–3 kg in weight.

In summer, June and July, the reproductive glands are very large, and the fish swarm near the surface of the water, often showing their dorsal fins out of water. This is the case in the northern parts of our waters, both on the Pacific and Japan Sea coasts. These mature fishes are associated with immature fishes. I have, however, not yet examined a tunny with fully ripe reproductive elements, and in August the reproductive glands are found spent. So that we are inclined to believe that the tunny spawn in offshore waters. Off the southern part of Kyushyu and also off the Pacific coast of the central part of Hondo, we find small immature tunnies in summer and autumn. In these waters the common tunny with ripe reproductive glands is not known. But it is difficult to believe that those immature fishes migrated from the northern waters.

Tunnies are caught more on dark nights, and before a storm. When the weather is warm with a southerly wind, tunnies come near the surface of the water, and a good catch by drift-nets is expected. On a day of northerly wind drifters do not go out fishing. They are said to swim against the current, especially when they are near the coast, hence they enter bays or inlets in low tide and seek off-shore grounds in high tide. Tunnies dislike a water of a low density, so that they do not approach the coast on a rainy day, nor approach the mouth of a river. They are found in a water of ca. 1.024–1.025 in density.

It is said that when a shoal of tunnies is frightened at something ahead of them, every tunny of the shoal turns back immediately just at the spot where it happens to be. Thus the hindermost fish lead the school when retiring. In 1921 a few immature tunnies were caught off Sendai in set-nets, at a depth of ca. 300 m. The nets were for a kind of deep-sea sharks. These tunnies were probably entangled, while the net was being hauled in, or when letting it out in the sea.

This species seems to descend to a depth of about forty metres below the surface of the water.

Genus **Parathunnus** gen. nov.

Cutaneous blood-vessels are found from the myotome of the seventh vertebra backward. The posterior cardinal vein does not communicate with the Cuvierian duct directly. At the margin of the exterior surface of the liver a few short venules are found. On the internal surface of the liver, conical masses of plexus of venules only are found, arteries not being divided in the masses. The right side of the stomach receives an artery from the right dorsal branch of the coeliaco-mesenteric artery.

Parathunnus mebachi (Kishinouye).

Mebachi, darumashibi, hirashibi, mebuto.

Figs. 4, 22, 47, 49.

Orcynus sibi, Kitahara, Journ. Fish. Bur. VI. 1, Pl. 1, Fig. 2, 1897
Thunnus mebachi Kishinouye, Sui. Gak. Ho, I, 19, Pl. 1, Fig. 11, 1915.

D. 14-15, 13, 9. A. 13, 9. Gill-rakers 8-10 + 18. Scales ca. 190.

Body very broad, the caudal portion short, and the head and eyes large. The dorsal outline of the body is much curved; but the ventral outline is much more curved. Scales in the corselet very large. Length of the head nearly equal to the height of the body in young specimens, but it becomes a little shorter in old individuals. The anus is nearly in the middle between the snout and the end of the caudal fin. Scales large ca. 190 in the lateral line, which has a gentle, wavelike elevation above the pectorals. Pectorals are long, gradually pointing towards the distal end. In large specimens they scarcely pass beyond the origin of the second dorsal, but in small specimens ca. 1 m in length, they reach the first dorsal finlet, and the vertical passing through the middle of the anal. Second dorsal and anal are only a little higher than the first dorsal, and they are comparatively narrow and falciform. The caudal fin is widely expanded, wider than the height of the body. Posterior portion of the first dorsal has the convex outline generally.

Air-bladder well developed. It is divided into two heads at the anterior end, which lie on both sides of the dorsal aorta and between the pharyngeal

muscles and cutaneous arteries. Kidneys are prolonged posteriorly to the segment of the thirteenth vertebra. Ureters of both sides run side by side in the narrow portion of the kidneys, and become confluent just at the posterior end of them.

Venules to the cutaneous vein are arranged in two alternate rows. Those of the exterior side pass over the cutaneous artery after joining many minute canals in the chiai plexus, and those of the inferior side unite to the cutaneous vein, just after joining minute canals. Arterioles from the cutaneous artery are arranged in two rows, one row on the remotest side from the accompanying cutaneous vein, the other on the nearest side to the vein. Arterioles in the former row are nearly twice more numerous, but smaller than those in the latter row. Thus two sheets of vascular plexus are formed from groups of the two rows of both arterioles and venules. Cutaneous arteries are sent from the dorsal aorta just below the eighth vertebra. The posterior cardinal vein is insignificant. Segmental veins in the precaudal region and in some anterior caudal segments running towards the vertebral column are divided up into minute vessels there. Venous blood from these vessels seen to be taken up by capillaries of the dark red portion of the lateral muscle.

Intestine longer than in the other Japanese tunnies, the third bend of it reaches nearly the first. Three lobes of the liver are thick, and triangular. Only a few, short, sparingly branched venules on the external surface of the middle and left lobes. Bulbous masses of vascular plexus are found on the inner side of the liver. These masses are slender and elongated, as the arteries in them take no part in the formation of the plexus, but run through them nearly straight.

Preopercle higher than broad, and the interopercle is nearly as high as broad. Haemal spines in the precaudal region are rather long. Parapophyses well developed, long, flattened at the distal end. They are directed downward from the ninth vertebra, and form the haemal arch from the tenth vertebra. Caudal vertebrae not so well developed as in other tunnies.

Back nearly black to greyish blue, sides silvery, and the iris silvery with bluish tint. Dorsal fins greyish, tinged yellow at the margin or the tip, finlets yellow. Pectorals are black at the dorsal side, but greyish at the ventral side, and the tip is sometimes washed with yellow. Ventrals are

greyish and tinged with yellow, while the anal is white with the yellow tip.
Anal finlets are greyish with yellowish margin. In young specimens under
7.5 kg in weight, the sides are greyish with a few colourless lines and series
of colourless dots, running transversely.

The flesh is pinkish in colour, rather soft, especially in young individuals.
Thus this species is considered a little inferior to the common tunny.

Very voracious fish, feeding on sauries, bonitos, luminous fishes, such as
Maurolicus, and allied kinds, cuttle-fish, and Amphipoda, *Sergestes*, *Acan-
theplayra*, etc.

This species lives in a deep layer of water, ca. 20–120 m below the
surface, 13–25° C in temperature, in offshore waters. Northern limit of
distribution is ca. 36° N. Caught at the southern coast of our country and
also at the Ogasawara Islands, Ryukyu Islands, and Taiwan. Not yet known
from the Japan Sea. In 1920 I observed a similar or the same species at
the market of San Pedro, but as I did not examine the anatomy in detail, I
can not tell exactly to which species it belongs. The broad body, the form of the
liver, hepatic venules, etc. were nearly the same as the Japanese species. Japanese
fishermen say that this species occurs in Hawaiian waters too. Probably widely
distributed in the deeper layer of the subtropical region of the Pacific Ocean.

At night the fish seems to come near the surface, as do other species of
tunnies, and on moon-light nights catches are generally good.

The fish grows to a total length of ca 2 m with a weight of ca 86 kg.
Fish of ca 70 cm is the smallest fish caught. I found skeletons of small
examples, ca 30 cm in length in the stomach of a *Neothunnus macropterus*,
caught near the Ogasawara Islands in January 1919.

HIROKATA YASHIRO (78) is probably the first author who has written
about this species, distinguishing it from the other species by the larger eyes.
Well known authors after him mention this species in their list of fishes. Thus
this species seems to have been caught in our country from about the begin-
ning of the nineteenth century.

Though this species has many distinctive characters, it is rather difficult
to identify it, especially when there is no other species to compare with.
Sometimes we receive reports that this species has been caught in pound-nets ;
but we are inclined to doubt the accuracy of the reports, as it is, so far as we

know, pelagic and does not approach the coast.

KITAHARA (48) identified this species with *Thynnus sibi* of SCHLEGEL (67), but the latter author writes that the species is very common, during summer months, and is caught in hundreds at a time by means of nets of large dimension. This statement is not adequate for the present species. Moreover there are no decisive characters in the description by SCHLEGEL, except the long pectorals and remarkable height of the body. Probably SCHLEGEL confounded this species with *Neothunnus macropterus*. CUNNINGHAM (10) considers this species to be identical with *Thynnus obesus* LOWE of the Atlantic; but our species differs from the latter in the colour of the second dorsal, and the anal at least. According to CUNNINGHAM these fins have "some black at edges, but little or no yellow." The descriptions of *Thynnus obesus* by LOWE (52) as well as CUNNINGHAM are very incomplete. It is allied to the present species in having large eyes, and a short, thickset figure. But as the other important structures of *Thynnus obesus* LOWE are unknown, it is impossible to ascertain the relation between these two species.

Recently the catch of this species is said to have much increased, due to the use of long snoods among snoods of normal length on a long line. The lower end of these long snoods will hang in a layer of water, deeper than 57 m under the surface of the sea. At present this species is very common in the grounds near the mouth of Tokyo Bay.

Genus **Neothunnus** gen. nov.

Cutaneous blood-vessels are found from the segment of the seventh vertebra. Posterior cardinal vein is united to the right Cuvierian duct, and the former vein is connected with a plexus of blood-vessels in the haemal canal, so that the haemal arch is remarkably wide. The first haemal arch is found in the 11th vertebra. On the exterior surface of the liver we find no minute veins. Caudal vertebrae elongated, and accordingly the caudal portion long.

Key to the the Japanese species of the genus *Neothunnus*.

Air-bladder present, second dorsal and anal much elongated.................*N. macropterus*.
Air-bladder absent, second dorsal and anal slightly higher than the
    first dorsal..*N. rarus*.

Neothunnus macropterus (Schlegel).

Kibata or kiwada, gesunaga, hashibi, hatsu, hirenaga, itoshibi,

kinhire, kimedi (immature).

Figs. 13, 19, 23, 45, 51.

Thynnus macropterus, Schlegel. Fauna Japon Poiss 98, Tab. 51; Day, Fish. India, 253, 18 2.

Orcynus macropterus, Kitahara, Journ. Fish. Bur. VI, 2, Pl. 2, Fig. 3, 1897.

Germo macropterus, Jordan & Seale, Bull. Bur. Fish. XXV, 228, 1906.

Thynnus macropterus, Kishinouye, Sui. Gak. Ho. I, 19, Pl 1, Fig. 12, 1915.

D. 13, 14, 9.   A. 14–15, 8–9.   Gill-rakers 9 + 21.   Scales ca. 270.

Body fusiform, elongated, head small, and the caudal portion long. Scales minute. Pectorals long, pass beyond the origin of the second dorsal, their dorsal and ventral outlines are nearly parallel to each other, and are connected by a short oblique side near the distal end. The second dorsal and the anal are much elongated, especially in a variety named itoshibi or gesunaga, the tips of these fins are whitish and reach to the base of the caudal. So far as I have examined there is no marked difference in anatomical structure between the long finned variety and the ordinary form, except in the length of the second dorsal and anal fins.

No venules on the surface of the liver, the left lobe of which is sometimes divided into two, and the right lobe is longer than the other. Pyloric coeca as a mass is shorter than the stomach. Intestine rather short, the third bend scarcely reaching the middle between the first and the second. The rectum is also short. Air-bladder narrow and long not divided at the anterior end. Thick strong connective tissue protects the ventral part of the air-bladder.

Venules to the cutaneous vein are arranged in one row on the side towards the lateral median line. These venules run over the external side of the cutaneous artery, after uniting many fine venules. Arterioles from the cutaneous artery are arranged in one or two alternate rows from the side near the lateral median line. Cutaneous blood-vessels are found at the surface of the lateral muscle behind the origin of the first dorsal. A cutaneous vein on each side of the body pours separately to the Cuvierian duct of the respective side, or is united to the cardinal vein below the ninth vertebra, and in the kidneys. The cardinal vein joins the right Cuvierian duct. In the haemal canal the cardinal vein is united with a plexus of short transverse

venules forming a dark red rod of plexus with similar arterioles from the dorsal aorta. It is remarkable that this rod of vascular plexus is found in the tunnies which want the conical vascular plexus on the inner side of the liver.

Kidneys are much elongated posteriorly, reaching to the segment of about the fifteenth vertebra. Ureters are united forming an acute angle under the thirteenth vertebra, and the common ureter is found behind the vertebra. Thus the ureters are shaped like the letter Y.

Vertebral column rather slender, and the second vertebra is nearly as high as broad. The posterior caudal vertebrae are remarkably elongated. Parapophyses long and flattened. They become more or less vertical in the eighth vertebra, turned downwards in the ninth vertebra, and an arch from the eleventh vertebra. Haemal canal wide, especially in the precaudal region, where the breadth of the cavity is nearly equal to that of the middle part of the respective vertebra. In one specimen I found the dorsal and ventral spines of the 36th vertebra short and nearly horizontal, instead of long and covering those of the next vertebra.

The colour is nearly black at the back, sides greyish with oblique transverse lines and series of dots of silvery white in alternation. Iris greenish yellow; first dorsal greyish tinged with yellow; tips of the second dorsal and dorsal finlets bright yellow; pectorals black on the inner side, greyish or sometimes yellowing on the outerside; ventrals greyish, tinged with yellow; anal and anal finlets bright yellow.

Distribution very wide, found in the Indo-Pacific region. Prefers warm water, 15–25° C mostly in the water of ca. 20° C. Northern limit of the distribution is ca. 35° N, but sometimes found beyond 40° N. Occasionally found in the Japan Sea, and is caught in Hokkaido, near Otaru, late in summer. Found in the Hawaiian waters and south Californian coast.

Large specimens measure more than 7 m in length, and ca 200 kg in weight, next in size to our common tunny.

They swim near the surface of the sea, especially in summer, and closely approach the land; but small immature fishes ca. 2 kg in weight are always in the off-shore grounds, accompanying a school of the striped bonitos. Larger ones are caught by troll-lines, long lines, drift-nets, circle nets, pound-nets, set nets, etc. Smaller ones are caught with rods and lines, circle nets,

more than 7 m in length, and ca **200** kg in weight, nex in size to our common tunny, etc.   The variety called gesunaga is said to be shyer than the ordinary form, not easily biting hooks, though it swims very near by and often touches them.   The longer-finned variety is said to be plentiful in autumn.

The flesh is beautifully pinkish, firm, and its taste is excellent.   Mostly consumed fresh, being much esteemed for "sashimi".   Many immature fishes are used for making "fushi" by smoking and drying after boiling in water.

They feed on flying fish, coffer-fish, some deep-sea fish, calamaries, pteropods, heteropods, Hyperina amphipods, *Squilla*'s larvae, and immature *Squilla*, mega-lopas of crabs, etc.

The spawning season of *Neothunnus macropterus* is not yet known.   Some specimens examined in autumn at Kyushyu are said to have contained large ovaries.

This species is allied to *Thynnus albacora* LOWE, so far as its external characters are concerned, so that GÜNTHER and CUNNINGHAM consider the former to be identical with the latter; but as in the case of the other exotic species the anatomy of *Thunnus albacora* has been little studied, therefore it is impossible to determine the question.

Neothunnus rarus (Kishinouye).

Koshinaga, bintsuke, hashibi, seiyoshibi, shiroshibi, tongari.

Figs. 24, 48, 64.

Thunnus rarus, Kishinouye. Sui. Gak. Ho, I, 23, Pl. 1, Fig. 13, 1915.

D. 13, 14, 9.   A. 14, 8.   Gill-rakers 5-6 + 15-17.   Scales ca. 220.

Body broad, head and eyes comparatively small, snout short, and caudal portion elongated.   Scales minute.   Curve of the lateral line above the pectoral very gentle.   The number of gill-rakers is minimum in our Plecostean fishes. Pectorals broad, lanceolate, scarcely reaching to the vertical from the last but one spine of the first dorsal.   Second dorsal and the anal are a little higher than the first dorsal.

Right lobe of the liver longest.   Air-bladder absent.   This is the only kind of the Japanese tunnies, which lacks it.   The posterior end of the kidneys is very narrow and extends nearly to the segment of the fifteenth vertebra.   Ureters are united to a common duct under the 12th vertebra.

Venules to the cutaneous vein are arranged in one row, on the side towards the lateral median line. These venules run side by side with the arterioles, and are united to a large vessel just before joining the cutaneous vein. The upper half of the diameter of the cutaneous artery is concealed under the cutaneous vein, and arterioles from the cutaneous artery are arranged in one or two rows, and more numerous than the venules, are sent from the exterior median line of the cutaneous artery. A cutaneous vein on each side of the body joins the cardinal vein below the ninth vertebra, and the cardinal vein pours into the right Cuvierian duct. Each cutaneous vein sends a large branch to the kidneys, before joining the cardinal vein. This is a renal portal vein. In the haemal canal a thick rod of plexus of transverse arterioles and venules is joined. The diameter of the plexus is a little broader than that of the vertebra in the precaudal region. The second branch of the coeliacomesenteric artery nourishes the right dorsal side of the stomach, spleen, and intestine.

Second vertebra wider than high. Transverse processes are not well developed and are turned downwards from the ninth vertebra, and the haemal arch is closed from the 11th vertebra, as in *Neothunnus macropterus*.

Back greyish blue, sides silvery greyish with colourless elongated spots in about five longitudinal rows. Dorsals, pectorals, and the ventrals blackish, but the tip of the second dorsal and the anal is washed with yellow. Anal fin silvery. Finlets, both dorsal and anal are yellowish with greyish margin.

Smallest tunny not only in our waters, but perhaps in the world. Fish about 70 cm in length and ca 6 kg in weight is common. Such a small tunny contained large and nearly ripe ovaries in February. Fish-mongers told me that a 12 kg fish is maximum.

Flesh is pale in colour, fatty and rather soft, but its taste is very nice.

Very limited in distribution. Found on the western and southern coast of Kyushyu and on the southwestern part of the Japan Sea. So far as I know, it is caught very near the coast, rather rare, and was quite unknown to science, till I got it from the market of Tokyo in 1913. People of the market considered it as a variety of *Neothunnus macropterus*. It is rather striking that this species remained unnoticed for a very long period. In autumn a few examples are said to be found every day in the market at Nagasaki.

Caught in pound-nets, and sometimes with rods and lines in littoral water

in association with small bonitos.

This species feeds, so far as I know, on small fishes only ;—one specimen contained two mackerels in its stomach, the second specimen fourteen examples of *Stolephorus gracilis*, and the third three half-beaks and some anchovies.

On December 17th, 1918, one of this species was found dead on the beach near the mouth of Gōnokawa, the largest river in Shimane-ken, probably scared by killer-whales or some other ferocious enemies.

Family KATSUWONIDAE Kishinouye.

Katsuwonidae, Kishinouye, 1917.

Body plump, rounded in cross-section, and naked outside of the corselet. Lateral line without a marked undulation above the pectoral fin. First dorsal very high at the anterior end, becoming suddenly low behind. Second dorsal remarkably lower than the first dorsal, and the anal and second dorsal are smaller than the ventrals. Pectorals very short and triangular. In this family the haemal canal is closed behind the middle of the precaudal region. Dentition weak, generally only one row of small teeth in both jaws. When teeth are found in other bones, they are arranged in one row only, never more. On the roof of the mouth-cavity no dentigerous calcareous plates. Tongue smooth with a ridge on each lateral side. No air-bladder. Pyloric coeca minute, numerous, uniform in size, and developed on the terminal branches of pyloric tubes, arranged on both sides of the duodenum. The loose and thick membrane surrounding the stomach in the Thunnidae is not found in this family. Three lobes of the liver unequal, and generally the right lobe is much elongated, except in the genus *Katsuwonus*. Intestine very short, without a loop. Rectum is nearly the same in length or a little longer than the remaining part of the intestine. The longitudinal folds of the internal layer of the duodenum extend to the straight small intestine, just to the beginning of the rectum.

The circulatory system which is related to the formation of the dark red portion of the lateral muscle, differ more or less from that of the Thunnidae. In the present family the cutaneous blood-vessels are also two in number, on each side of the lateral median line ; but the hypaxial vein is divided to renal portals, and the hypaxial artery passes through the kidneys, taking a slight downward course, and runs backward anterior to and above the series of the ribs. Except

in the case of the genus *Katsuwonus*, the hypaxial blood-vessels are much smaller and shorter than the epaxial, and the plexus of blood vessels surrounding the dark red portion of the lateral muscle are united to the epaxial blood vessels only. Indeed the epaxial blood vessels of the Katsuwonidae seem to correspond to the entire cutaneous system of the Thunnidae, and the hypaxial vessels of the former seem to be sui generis. The posterior cardinal vein joins the right Cuvierian duct, and joining this cardinal vein is a small renal vein. The interhaemal rod of the vascular plexus attains the utmost development in *Katsuwonus* and *Euthynnus*. The rod is thicker than the diameter of the vertebral column, and is protected by the bony trellis formed by haemal processes of the column, from the enormous development of the inferior foramen. In the genus *Auxis*, however, the interhaemal rod of the vascular plexus is very thin, and the inferior foramen is formed in a few caudal vertebrae only, having no relation with the vascualr plexus.

Kidneys much elongated. Ureters are nearly separate, running almost parallel to each other in the posterior slender portion of the kidneys. The spleen is smaller than that of tunnies and is situated at the anterior portion of the visceral cavity.

In the hypaxal dark red portion of the lateral muscle, just below the series of intermuscular bones a large strong tendon from the second vertebra is sheathed with thin layers of some muscle segments, from the myotomes of the third and some succeeding vertebrae. Thus in each epaxial portion of the lateral muscle two concentric rings of muscle segments are found in the cross-section. This is quite characteristic of the Katsuwonidae. The axial side of the lateral muscle meets the axial skeleton in the epaxial as well as the hypaxial portion, and the dark red portion is more voluminous than in the Thunnidae.

The vertebral column is very firm, light, and compact, allowing no lateral motion. In anterior precaudal vertebrae the neural canal is separated from the canal of the spinal ligament by a thin bony septum as in the Scombridae. Neural process of the first vertebra is more or less united to the centrum and the posterior dorsal zygapophyses are very well developed in the vertebra. Parapophyses are quite abortive.

Dentigerous ossicles on the gill-arches are large and are arranged in one row only. Internal gill-rakers are well developed.

Long intermuscular bones on anterior precaudal vertebrae, which have their distal end at the surface of the body are found as far as the seventh vertebra. From the eighth vertebra backward some long intermuscular bones are also found, but they are not ossified in the middle portion. Intermuscular bones are well developed and are found on every vertebra, except those which have the lateral keel, and behind the attachment of intermuscular bone there is a pointed tubercle in the vertebra.

External and internal portions of the clavicle are perpendicular to each other.

Below each eye an oval black spot is generally found. This colour spot is distinct, especially in the genus *Auxis*.

Fishes of this family feed chiefly on small fishes and medium sized plankton. They are liable to perish sooner than those of the Thunnidae.

<div align="center">Key to the genera of the Katsuwonidae.</div>

The first dorsal is continuous to the second, a pair of foramen on the dorsal
    surface of the skull, inferior foramen of vertebrae well developed, thus
    the so-called trellis is formed.
        Both epaxial and hypaxial blood-vessels under the skin are equally
            well developed, teeth in both jaws only, vertebrae 20–21 . . . . *Katsuwonus.*
        Hypaxial blood-vessels under the skin are atrophied; epaxial blood-
            vessels run just above the lateral median line of the body,
            teeth in both jaws, palatines, and sometimes on the vomer too,
            epihaemal spines well developed, vertebrae 20–19. . . . . *Euthynnus.*
The first dorsal is not continuous with the second; no foramen on the dorsal
    surface of the skull; hypaxial bloodvessels under the skin are atrophied;
    teeth in jaws only; inferior foramen scarcely developed; epihaemal spines
    well developed, long; vertebrae 20–19 . . . . *Auxis.*

Genus **Katsuwonus** Kishinouye.

Katsuwonus, Kishinouye, Sui. Gak. Ho. I. 21, 1915.

Body plump, rounded in cross-section, and we find a few minute scales scattered in the thick skin, outside of the corselet. Teeth in jaws only, about forty in each. Gall-bladder long, nearly free from the liver, and runs along the dorsal side of the intestine.

The cutaneous circulatory system is unique. A pair of cutaneous arteries branch just behind the insertion of the pharyngeal muscles as in the tunnies and other bonitos; but passing through the kidneys the arteries turn outward and

forward, instead of turning more or less backward as in the other plecostean fishes. Each artery reaching to the myotome of the first rib is divided into two arteries, epaxial and hypaxial. The epaxial artery runs below the first rib, while the hypaxial artery runs above the rib. These two arteries, are nearly equally developed, and are separated from each other at a distance of 6-8 times the breadth of the blood-vessels. These arteries do not form a loop at the caudal region. The cutaneous artery and cutaneous vein lie in juxtaposition, nearly flat at the surface of the body. Arterioles and venules connected with these cutaneous canals run in opposite directions, along the surface of the body, and they are not so numerous as in the tunnies. The rod of the vascular plexus in the haemal canal is called kurochiai by fishermen, and it is thicker than the diameter of the vertebral column.

This genus is closely allied to the genus *Neothunnus* of the Thunnidae and stands quite near the genus *Euthynnus*. Number of the precaudal vertebrae corresponds to that of *Euthynnus*, while the number of caudal vertebrae is equal to that of the Thunnidae. Thus the total number of vertebrae is 41, while in all the other genera of the plecostean fishes the number is always 39.

Only one cosmopolitan species is known from the temperate and tropical regions of the world.

Katsuwonus pelamis (Linnaeus).

Katsuwo, magatsuwo, mandaragatsuwo.

Figs. 5, 14, 19, 25, 52, 57.

Scomber pelamis, Linnaeus, Syst. Nat. X, 297, 1758.
Thynnus pelamys, Cuv. & Val., Hist. Nat. Poiss. VIII, 113, Tab. 214, 1831; Schlegel, Fauna Japon. Poiss, 96, Tab. 49, 1850; Günther, Cat. Brit. Mus. II, 334, 1860.
Gymnosarda pelamis, Dressler & Fesler, Bull. U. S. Fish Comm. VII, 436, 1889, Jordan & Evermann, Fish. N. & M. America, I, 868, 1896.
Euthynnus pelamis, Tanaka, Fish. Japan, I—X, 140, Pls. 37, 39, 40, 1912.
Katsuwonus pelamys, Kishinouye, Sui. Gak. Ho, I, 24, Pl. 1, Fig. 14, 1915.

D. 12-17, 11-14, 8.   A. 11-15, 7.   Gill-rakers 15-20+36-39.

Body plump, sharply pointed at both ends. Lateral line slightly curved upward above the pectorals and bent below the second dorsal, and nearly horizontal in the caudal portion. Gill-rakers numerous, very thin, and their inner margin undulating. The right lobe of the liver is small and slender.

Plexus of venules from the posterior cardinal vein forms a long continuous

mass like a rod with the plexus of arterioles from the dorsal aorta to the vertical of the ninth vertebra; but anterior to the vertebra the plexus is discontinued and is divided only into small bundles of venules.

Kidneys are much elongated posteriorly. In the haemal canal, below the vertebral column, there is also a renal body.

The back is dark bluish violet, with some transverse light coloured markings, the sides are silvery with four or more dark coloured longitudinal bands on each side. Dorsals, dorsal finlets, pectorals, and the anal are dusky. Iris silvery, with a greenish shade.

The bonito lives in the clear blue water of the Kuroshiwo, 20–30° in temperature, and 1.024–1.026 in specific gravity. On the Japan Sea, this fish is caught in small numbers, late in autumn or in winter only, there being no special fishing for this fish. On the northeastern coast of Hondo, the bonito is generally caught in grounds very far from the land, 100–200 miles off. In spring bonitos begin to migrate northward, and reach the ground off the southeastern coast of Hokkaido in summer. Sometimes the fish makes big shoals of several hundreds to thousands, and when they attack a school of small fishes, such as sardines and anchovies, they surround the latter till the victims form a dense spherical mass. Then the bonitos feed gradually on the stragglers from the school, swimming around outside the mass. Generally they feed on the medium sized plankton:—amphipods, *Squilla*'s larvae and other crustaceans, pteropods, heteropods (chiefly *Atlanta*), calamaries, and immature or small fishes, etc. According to experienced fishermen, bonitos are said to contain plenty of food in their stomach, when they are caught in large quantities with rods and lines; but almost no trace of food is found in their stomachs, when refuse to bite a hook. This is true also of the tunny fishery by means of long lines. Though bonitos and tunnies are very voracious and bite a hook easily and eagerly, especially when they are in a frenzy of competition to get as much food as possible, yet they are cool and cautious when there is only a little food. And in midsummer when the reproductive elements become ripe, bonitos seem to fast. In the water round Ryukyu and the adjacent islands we find small bonitos about 20 cm in length in August, and in January I have obtained small bonitos ca. 30 cm (without caudal) from the stomach of tunnies, caught near the Ogasawara

Islands. These immature fishes are very slender, have faint longitudinal colour bands on the sides and the sooty belly. These fishes are most probably yearlings, hatched late in spring of the preceding year.

Bonitos are sensitive fishes, being frightened away when the water is stained with blood, when a fellow fish is struggling furiously in a net, or when a fellow fish makes a narrow escape from a net or a hook. Therefore shark-fishing with a long line in the fishing ground of the bonito is considered in several districts to be harmful to bonito-fishing, as the death-combat of sharks is generally accompanied with blood-shed, which scares the bonito away. Long lines for the bonito are also believed to be injurious from a similar cause. Drift net fishing for bonitos and tunnies is also hated by the bonito-fishermen, as well as the circle-net fishing for these fishes. Bonitos are very active and powerful, but they are not tenacious of life and can not withstand unfavourable conditions long. Thus when caught in a drift net or a drift long line they very soon succumb. In this point bonitos seem to differ very much from tunnies.

Bonitos are very good swimmers, their velocity being roughly estimated to be more than 25 miles an hour. They migrate in shoals in search of food, and do not stop at any particular spot for a long time, though they often remain for a while round shallow banks in a warm clear water, as several kinds of small fishes are always found in such places.

Bonito-fishing is carried on at the Pacific coast of our empire, in Hokkaido in the north, as an important industry. On the west coast of Kyushyu and in the waters round the Ryukyu Islands and Taiwan this fishery also thrives. Bonitos are chiefly caught with rods and lines, alluring a shoal of fish with live baits thrown from the boat, as the net-fishing is not suitable, owing to the clearness of the water. Long lines are sometimes used. The snood is 3–4 m in length and the distance between two consecutive snoods is about 8 m. These lines are slender and not very strong.

Bones of this fish are found in the remains of shell-mounds in the north-eastern part of Hondo. In the "Yengishiki," a classical work on ceremonies in the imperial court, etc., compiled in 927, many kinds of food prepared from the bonito are enumerated, and these articles were given as tribute to the government and the imperial court. In an article in "Tsurezuregusa," a well-

known literary work by KENKO YOSHIDA at the time of the Ashikaga Shōguns, it is stated that the bonito was valued in Kamakura at that time, though it had been condemned as an inferior fish in previous times. In the time of the Tokugawa Shōguns, however, an extravagant price was paid for an early arrival of bonitos in late spring in Yedo, as was the case with the mackerel in London in former days. Many short poems called "hokku," mostly satirical, were written about the early bonito at the time, and many extraordinary tales are still told about it. At that time the fish was eaten raw as sashimi. Early in summer the generative organ of the bonito is still small, and the climate is not yet so hot as to cause quick putrefaction of the fish. Therefore bonitos of prime condition were obtained in this season, and at this time the fish was caught near the coast and was sent by express rowing boats, manned by about ten men to each boat. Thus the gastronomers of Yedo were able to taste bonitos in a prime condition, and to enjoy the very rich flavour a few hours after they were caught. At present bonito-fishing is conducted in very remote grounds only, and though caught in early spring, the fish are brought to market, preserved in ice, two or three days after capture. Consequently their choice flavour being lost, early bonitos are nowadays no longer estimated by epicurians.

It grows to a length of about one metre, generally 18 kg in weight, rarely 25 kg. Spawning seems to take place from May to August. Tunnies and spear-fishes are enemies. *Rhynchobothrium* is inevitably found in the flesh of the bonito, especially abundant in autumn. Bonitos caught in off-shore waters contain a much smaller quantity of fat than those caught in littoral waters. The flesh of bonitos is longitudinally cut into four pieces and then smoked and dried after boiling in water. This dried article called "katsuwobushi" is a necessary article in our household, being used as a condiment after shredding. Its annual production is ca 11,000,000 kg.

Genus **Euthynnus** Lütken.

Euthynnus, Lütken, MS. in Jordan & Gilbert, Syn. Fish. N. America, 429, 1883.

Body plump, rounded, and naked outside of the corselet. Mouth rather large, maxillary reaching the vertical from the centre of the eye. Teeth more developed in size and number than in the other genera of the Katsuwonidae.

They are found not only in both jaws, but also on the palatines and some-times on the vomer too. Teeth on the palatines are in single row. The right lobe of the liver much elongated as in the genus *Auxis*. It is remarkable that the chief cutaneous artery runs along the dorsal external side of the chief cutaneous vein, quite contrary to the case in all the other forms of the plecostean fishes, and the dorsal segmental branches of the chief cutaneous vein pass over the accompanying artery, which is a little more or less deeply imbedded in the muscle. The degenerated hypaxial cutaneous artery lies ventral, that is external and similarly to the accompanying vein. Hypaxial, cutaneous blood-vessels are bent in a zigzag line. They have no connection with the vascular plexus, nourishing the dark red portion of the lateral muscle. The subspinal rod of the vascular plexus is also well developed, but the rod is separated from the vertebral column by the development of the epihaemal process, between the vertebral column and the haemal canal. Thus the inferior foramen is remarkably larger than in the genus *Katsuwonus*.

Dark markings in the naked part of the back, and generally some greyish spots in the pectoral region above the ventrals.

Fishes of this genus attain about the same size as the striped bonito. They are degenerated forms, derived from the genus *Katsuwonus*. Voracious fishes of temperate and tropical seas, not forming large schools, and often ap-proaching the coast. Until recently only one species was known, but I have found other two species in the Pacific, quite different from the Atlantic species.

Key to the species of the genus *Euthynnus*.

Vomerine teeth present.
    Dark oblique bands on the back........ ....*E. yaito.*
    Dark longitudinal bands on the back. ....*E. lineatus.*
Vomerine teeth absent. ....*E. alleterata.*

Euthynnus yaito Kishinouye.

Yaito, hiragatsuwo, obosogatsuwo, segatsuwo, suma, uramawarigatsuwo, wata-nabe, yaitopara, yaitosuma.

Figs, 26, 54, 58.

Thynnus thunnina, Schlegel, Fauna Japon. Poiss. 95, Tab. 48. 1850.
? *Thynnus affinis*, Cantor, Cat. Malay. Fish. 106, 1850.

Euthynnus yaito, Kishinouye, Sui. Gak. Ho, I, 22, Pl. 1, Fig. 15, 1915.

D. 15–16, 12–13, 8.   A. 13, 7.   Gill-rakers 8–10 + 22–24.

Vomerine teeth present. This character clearly separates this species from the allied species of the Atlantic, with which it has been hitherto confounded, as the presence of the vomerine teeth in this species had been overlooked. Vomerine teeth are arranged in one row on a longitudinal ridge. Palatine teeth are also on one row only. The upper jaw has 27–30 teeth, while the lower has 24–27. Gill-rakers in this species are fewer in number than in the allied species of the Atlantic. The latter has 11–28.

The cutaneous artery sends arterioles from the inner and lower side in one row, while the venules to the cutaneous vein are arranged in two rows, alternate on the inner side. To the epaxial cutaneous blood vessels both the upper and lower segmentary branches are connected.

Skull broad, its breadth is contained 1½ in its length. The alisphenoid and prootic meet, and form a bridge over the groove of the prootic. Two pairs of the auxiliary intermuscular bones are found on the dorsal surface of the exoccipitals, one pair of which is situated just above the foramen of the spinal cord, and the other at the lower end of paired vertical ridges continued from the top of the epiotic. The supraoccipital crest is very broad, and its vertical side meets the fused median ridge of the exoccipitals. In the specimen figured in fig. 53 the caudal vertebrae are very long.

Back bluish black with many dark oblique bands. Belly silvery with three or more greyish spots below the pectorals. Fins black or greyish, the ventrals are partly black and fringed with chalk-white. Iris silvery with beautiful reflection. A black spot under each eye.

Found chiefly in the southern part of our empire. The northern limit of distribution seems to be near Chiba-ken on the Pacific coast. Lately Mr. K. NOMURA sent me a specimen of this species, caught near Tsuruga, Fukui-ken in October, 1921. This is the first specimen from the Japan Sea. Among specimens of scombroid fishes from the Dutch Indies, kindly sent by Mr. GOBEE, I found three immature forms of this species, but the southern limit of distribution is not yet determined.

This species is rather rare, and is not found in schools. As it approaches the shore, a few examples are sometimes caught in drag seines and pound-nets.

Also caught with rods and lines associated with bonitos and immature tunnies.

Voracious fish, feeds on small fishes and medium sized plankton. When this fish encounters a school of small fishes, it darts into the crowd and scatters them in the same way as the pelamids and tunnies.

This fish attains a total length of ca 60 cm, and a weight of ca 3½ kg, but rarely a fish of one metre and more than 10 kg in weight is found.

Spawning seems to take place about in May in Taiwan. A young specimen measuring 11.5 cm in length was captured near the mouth of Keelung Harbour, on August 29, 1917. It is slenderer than the adult, and has about a dozen dark transverse bands, more or less oblique. These bands pass the lateral line downwards.

Flesh more or less firm and pretty good in taste.

Thynnus affinis of CANTOR seems to be identical with this species; but as he denies the presence of the vomerine teeth, it may be a different species. Moreover the colour of fins differs in *Thynnus affinis*. It is said that the second dorsal, anal, and their spurious fins are pale brownish yellow, edged and washed with black; while the caudal is yellowish buff, washed with brownish in the centre.

Euthynnus lineatus Kishinouye.

Euthynnus lineatus, Kishinouye, Sui. Gak. Ho, III, 113, 1920.

This species was created on a single specimen from Manzanillo, Mexico, collected by Mr. Naotaro Ota, in 1915. It differs from the other known

Fig. Z. *Euthynnus lineatus* 1 4.

species by the presence of about three longitudinal dark lines or rather bands in the naked portion above the lateral line. One row of teeth on the vomer and palatines as in *Euthynnus yaito*. In the new species the head is larger than in the other species. The specimen examined is 48 cm in the total length. In the thoracic part there are some spots or rather very short bands. Caudal portion very slender and short.

Genus **Auxis** Cuvier.

Auxis Cuvier, Regne Anim. II, 119, 1829.

Body rounded in cross-section, fusiform, and more elongated than in *Katsuwonus* and *Euthynnus*. Caudal portion remarkably short, while the precaudal portion is very long. Snout short, mouth small. Teeth in both jaws only. Fins small, especially the second dorsal, anal, and caudal. Posterior portion of the first dorsal has disappeared, and the fin is nearly triangular in shape, and is not continuous to the second dorsal. In the median prolongation of the corselet, we find no indentation at the ventral margin behind the pectorals. Lateral line slightly curved with small undulations. Tongue flat, smooth, and silvery.

Basioccipital together with the parasphenoid form paired horn-like processes behind to support the first vertebra above. Exoccipitals fused to one piece of bone, with a prominent dorsal median crest, just below the supraoccipital crest, thus affording a strong hold for the insertion of the lateral muscles. Deep transverse depression along the suture between the prootic and alisphenoid, corresponding to the ventral groove in the optic lobe of the brain. At the anterior border of the depression the alisphenoid is produced to a shelf to partly cover the depression. Pterotic process long and broad horizontally. The sphenotic does not appear in the dorsal side of the skull. Antero-superior corner of the subopercle produced. One pair of auxiliary intermuscular bones on the coalesced exoccipitals, just above the foramen for the spinal cord. Some intermuscular bones behind that of the 8th vertebra are divided into two portions and are connected by a ligament.

The first vertebra is not closely coalesced to the skull, and the upper posterior zygapophyses are long and large for the attachment of the clavicular ligament. The neural process of the first vertebra is weak and small. In the

second vertebra the neural process and the lateral transverse processes are remarkably large. The former is for the attachment of the muscle of the first dorsal, and the latter for the attachment of a pair of strong tendons from the centre of paired small cones of myotomes. First three vertebrae have a pair of strong ridges or pillars at the ventral side respectively.

The centrum of the succeeding vertebrae is shaped like an hourglass, as longitudinal ridges are scarcely developed in them. Lateral keels are more or less developed in the majority of the caudal vertebrae, though many of them are not developed along the whole length of the side. In the precaudal vertebrae, ventral processes arise from the anterior end only, and they are united into a median rod, the epihaemal process of some length. At the distal end the rod is separated to parapophyses. The haemal arch and haemal spine are found in caudal vertebrae only. The epihaemal process is turned more or less forward in the caudal region as well, while the haemal processes are turned backward. Both neural and haemal processes from the vertebrae, with the exception of some caudal ones, are laterally compressed. Even in the first caudal vertebra, the epihaemal process is more or less turned forward and the process of that vertebra makes nearly a right angle with the haemal arch. The so-called trellis formed on the ventral side of the vertebral column is scarcely developed in this genus. Spurious internearals are found between the two dorsals.

Epaxial cutaneous blood-vessels run near the lateral median line, and are united to segmental branches of both epaxial and hypaxial sides. These blood-vessels form sheets of the vascular plexus round the dark red portion of the lateral muscle, as the hypaxial cutaneous blood-vessels are atrophied as in the genus *Euthynnus*, and take no part in the formation of the plexus. The rod of the vascular plexus between the parapophyses in the precaudal region and in the haemal canal in the caudal region is thin and much degenerated.

The dark red portion of the lateral muscle the chiai is broadest near the vertebral column, as the chief axial blood-vessels are far removed from the latter. A comparatively large portion of the lateral muscle is coloured dark red. Besides a concentric sheath of muscles round the strong tendon from the second vertebra, there is another smaller concentric sheath of muscles round another tendon on the external side of the anterior part of the cutaneous blood vessels.

The dendritic course of the hepatic vein may distinctly be seen on the exterior side of the liver. The right lobe of the liver is exceedingly long, the other lobes are short and rather indistinct. The mass of the pyloric coeca is much shorter than the stomach. Kidneys are elongated. Two ureters are separated and open at the dorsal, anterior end of the bladder. Sexual gland when ripened develops backward along both sides of the thick row of interspinous bones of the anal fin. This is due to the narrowness of the abdominal cavity.

The back is dark greenish, it becomes dark bluish after death. Several oblique bands in the scaleless part above the lateral line. Belly silvery, with irridescent reflections. Oval dark spot below each eye.

Very widely distributed in the temperate and tropical waters. In warm seasons the fish approaches the shore, often in large schools, and is caught with seines, pound-nets, drift nets, rods and lines, etc. This fish is also found in the Japan Sea. It swims in the deeper strata of water in cold months, and disappears in winter from our coasts.

Very small in size, generally ca 30 cm in length.

The fish feeds on small plankton and small fishes, such as *Atherina*, *Stolephorus*, *Sprattelloides*, immature forms of *Engraulis*, etc. It is inferior in taste, as it is coarse and moreover very perishable.

In our waters there are two different species of fish belonging to this genus. They resemble each other so closely that they have long been confounded by naturalists, and were considered to be the same species as the Atlantic congener.

Key to the Japanese species of the genus *Auxis*.

Body more or less compressed, only a few scales are found on both sides of
   the lateral line in the posterior part of the body; inferior foramen
   present in the last two vertebrae with the epihaemal spine (26th and 27th......*A. hira*
Body nearly rounded in cross-section, several rows of scales on both sides of
   the lateral line, no inferior foramen in the vertebrae with the epihaemal spine....*A. maru*

Auxis hira Kishinouye.

Hiramedika, hiragatsuwo, hirasohda, obosogatsuwo, shibuwa,
soma, suma, etc.

Figs. 55, 59.

Auxis hira, Kishinouye, Sui. Gak. Ho. I, 23, Pl. 1, Fig. 16. 1915.

D. 10–11, 12, 8. A. 13, 7. Gill-rakers 9 + 30.

Body more or less compressed, its height is nearly equal to the length of the head. Middle limb of the conselet ends a little behind the pectoral, and one or two rows of minute scales are found on either side of the lateral line.

The hypaxial dark red portion of the lateral muscle is larger than the epaxial. Myotomes of some body-segments seem to be subdivided in the dark red portion.

Long intermuscular bones, the tips of which are found to reach the surface of the body to the 11th vertebra, and the last four of them are not entirely ossified, leaving the middle part fibrous. The lateral process of the second vertebra is longer than the vertebra itself. The haemal arch of the first caudal vertebra is bent with a more or less obtuse angle. In the 23rd and some succeeding vertebrae there are paired downward processes from the end of the haemal process, and these processes nearly reach the origin of the haemal spine of the preceding vertebrae.

This species is very widely distributed. Its northern range reaches to Hokkaido and is known from the coasts of the Japan Sea, Korea, Ogasawara Islands, Ryukyu Islands, Formosa, etc. Caught in large numbers in southern regions.

This species grows to a weight of ca. 1.5 kg.

Seems to spawn in summer. Reproductive elements are nearly ripe in August.

This species is not so numerous as the other but the flesh being firmer is superior to the other in quality.

Auxis maru Kishinouye.

Marumedika, chiboh, dainanpo, magatsuwo, manba, mandara, marugatsuwo, nodoguro, rohsoku, subota, uzuwa, etc.

Figs. 2, 15, 27, 56, 60.

? *Auxis tapeinosoma*, Blecker, Verh. Bat. Gen. XXVI, 98, Tab. 7, Fig. 1, 1854-57.
? *Scomber thazard*, Lacépéde, Hist. Nat. Poiss. III, 9, 1802
Auxis rochei, Kitahara, Journ. Fish. Bur. VI, 3, Pl. 4, Fig 9, 1897.
Auxis maru, Kishinouye, Sui. Gak Ho, I, 24, Pl. 1, Fig. 49, 1915.

D. 9-10, 11-12, 8.   A. 13, 7.   Gill-rakers 10+36.

Body fusiform, nearly rounded in cross-section, and its height is smaller

than the length of the head. The middle limb of the corselet is prolonged backward nearly the entire length of the lateral line.

The dark coloured portion of the lateral muscle is nearly equally large in the hypaxial and epaxial portions.

Depression along the suture between the prootic and the alisphenoid is sharply defined and narrow, and the shelf at the anterior border of the depression is obsolete. Only two intermuscular bones have the middle portion non-ossified. The lateral process of the second vertebra is short and thick. Neural process of some anterior vertebrae is not so broad as in the preceding species. The haemal arch of the first caudal vertebra makes a right angle with the epihaemal spine. From the lower end of the epihaemal spine a pair of short free processes is produced downward and forward in some caudal vertebrae. Free parapophyses from the lower end of the epihaemal process are short, and are but a little separated from each other.

This species seems to be more abundant than the preceding species. In distribution nearly the same as the latter. Known from South-Manchuria as well. Caught in pound-nets, set-nets, drift nets, rods and lines, etc.

Grows to a weight of ca. 640 g, the smallest species in the Plecostei.

Very poor food-fish, consumed fresh or salted.

Auxis tapeinosoma of BLEEKER seems at first sight to be identical with this species, but not exactly, as the dorsal finlets of the former are characterised as 9 in number.

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Explanation of Plates.

PLATE XIII.

Fig. 1. *Scomber japonicus.* Skin, hypaxial lateral muscle, and a part of the caudal portion removed, showing the vascular system, viscera, intermuscular tendons, etc.

Fig. 2. *Auxis maru.* Skin, pale coloured portion of the hypaxial lateral muscle removed, together with an external part of the dark red portion removed between the 13th to 18th vertebra. In the cross-sections of the lateral muscle, both epaxial and hypaxial of the dark red portion are represented. Two small cones of muscles round a respective tendon, axial and cutaneous (lower canal is not represented) vascular systems are shown.

PLATE XIV.

Fig. 3. *Thunnus orientalis.* Skin, anterior portion of the hypaxial lateral muscle, and a part of gills and gill-cover have been removed, exposing the cutaneous vascular system and the viscera.

Fig. 4. *Parathunnus mebachi.* Skin, hypaxial lateral muscle, most part of viscera, and the caudal peduncle removed, to show the vertebral vascular system, cutaneous vascular system, intermuscular tendons, etc.

PLATE XV.

Fig. 5. *Katsuwonus pelamis.* Skin, and hypaxial lateral muscle removed, to show the vertebral and the hypaxial cutaneous vascular system, viscera, etc.

Fig. 6. *Cybium niphonium.* Greater part of the muscle removed at the anterior part, leaving the intermuscular bones, the membrane connecting them, intermuscular tendons, median proximal portion of myocommata, and segmental blood vessels.

PLATE XVI.

Middle transverse section of vertebrae. The dotted line in the figures separates the caudal vertebrae from the precaudal, and the numeral in a smaller type is the number of a vertebra from the anterior end.

Fig. 7. *Scomber japonicus.*

Fig. 8. *Grammatorcynus bilineatus.*

Fig. 9. *Cybium niphonium.*

Fig. 10. *Acanthocybium solandri.*

Fig. 11. *Sarda orientalis.*

Fig. 12. *Gymnosarda nuda.*

Fig. 13. *Neothunnus macropterus.*

Fig. 14. *Katsuwonus pelamis.*

Fig. 15. *Auxis maru.*

PLATE XVII.

Cross-sections of the lateral muscles and the dorsal and ventral carinales (one half moiety), showing the relation between the dark coloured portion and blood-vessels, and also the number of myotomes.

Fig. 16. *Scomber japonicus.*

Fig. 17. *Sarda orientalis.*

Fig. 18. *Neothunnus macropterus.*

Fig. 19. *Katsuwonus pelamis.*

PLATE XVIII

Cutaneous blood vessels and minute blood vessels connected with them in the dorsal part of the body (demidiagramatic).

Fig. 20. *Thunnus germo.*

Fig. 21. *Thunnus orientalis.*

Fig. 22. *Parathunnus mebachi.*

Fig. 23. *Neothunnus macropterus.*

Fig. 24. *Neothunnus rarus.*

Fig. 25. *Katsuwonus pelamis.*

Fig. 26. *Euthynnus yaito.*

Fig. 27. *Auxis maru.*

PLATE XIX.

Scomber japonicus.

Fig. 28. Variety "hirasaba."

Fig. 29. Variety "gomasaba" or "marusaba" (immature).

Fig. 30. Skeleton. *a.* dorsal surface of the skull. *b.* Ventral surface of the skull *c.* Ventral view of the anterior precaudal vertebrae to the first vertebra with the haemal arch closed. *d.* Dorsal view of the vertebrae of the caudal peduncle.

PLATE XX.

Fig. 31. *Acanthocybium solandri.*

Fig 32. *Cybium niphonium.*

Fig. 33. *Sarda orientalis.*

PLATE XXI.

Fig. 34. *Cybium chinense.*

Fig. 35. *Cybium koreanum. a.* Ventral view of the skull. *b.* Dorsal view of the skull. *c.* Side view of the skull.

PLATE XXII.

Fig. 36. *Cybium commerson.*

Fig. 37. *Gymnosarda nuda.*

Fig. 38. Skeleton of *Gymnosarda nuda*. *a*. Dorsal view of the skull. *b*. Ventral view of the skull. *c*. Ventral view of anterior precaudal vertebrae to the first vertebra in which the haemal arch is closed. *d*. Dorsal view of the vertebrae of the caudal peduncle.

PLATE XXIII

Fig. 39. Skeleton of *Acanthocybium solandri*. *a*. Dorsal view of the skull. *b*. Ventral view of the skull. *c*. Ventral view of anterior precaudal vertebrae to the first vertebra with the closed haemal arch. *d*. Dorsal view of the vertebrae of the caudal peduncle.

Fig. 40. Skeleton of *Cybium chinense*. *a* Dorsal view of the skull. *b*. Ventral view of the skull with following vertebrae. *c*. Dorsal view of vertebrae of the caudal peduncle.

PLATE XXIV.

Fig. 41. Skeleton of *Cybium niphonium*. *a*. Dorsal view of the skull. *b*. Ventral view of the skull and precaudal vertebrae. *c*. Dorsal view of vertebrae of the caudal peduncle.

Fig. 42. Skeleton of *Sarda orientalis*. *a*. Dorsal view of the skull. *b*. Ventral view of the skull. *c*. Ventral view of anterior precaudal vertebrae. *d*. Dorsal view of vertebrae of the caudal peduncle.

PLATE XXV.

Fig. 43. *Thunnus orientalis*. Immature specimen, about six months old.
Fig. 44. Skelton of the above.

PLATE XXVI.

Fig. 45. *Neothunnus macropterus*. (Immature).
Fig. 46. *Thunnus germo*.

PLATE XXVII.

Fig. 47. *Parathunnus mebachi*. (Immature).
Fig. 48. *Neothunnus rarus*.

PLATE XXVIII.

Fig. 49. Skull and vertebral column of *Parathunnus mebachi*.
Fig. 50. Skull and vertebral column of *Thunnus orientalis*.
    a. Dorsal view of the skull. *b*. Ventral view of the skull. *c*. Ventral view of the anterior vertebrae till the first haemal arch is closed. Anterior Zygapophyses of the second vertebra are represented in *Th. orientalis* only. *d*. Dorsal view of the caudal vertebrae. (*Th. orientalis*, ventral view?)

PLATE XXIX.

Fig. 51. Skull and vertebral column of *Neothunnus macropterus*.
Fig. 52. Skull and vertebral column of *Thunnus germo*.

a, b, c, d. The same as in the preceding plate.

PLATE XXX.

Fig. 53. *Katsuwonus pelamis.*
Fig. 54. *Euthynnus yaito.*

PLATE XXXI.

Fig. 55. *Auxis hira.*
Fig. 56. *Auxis maru.*

PLATE XXXII.

Fig. 57. Skull and vertebral column of *Katsuwonus pelamis.*
Fig. 58. Skull and vertebral column of *Euthynnus yaito.*

a. Dorsal view of the skull. *b.* Ventral view of the skull. *c.* Ventral view of the anterior vertebrae, till the first haemal arch is closed. *d.* Dorsal view of the caudal vertebrae. *e, f, g.* Three stages of haemal processes till they unite to form the haemal canal in precaudal vertebrae.

PLATE XXXIII.

Fig. 59. Skull and vertebral column of *Auxis hira.*
Fig. 60. Skull and vertebral column of *Auxis maru.*

a. Dorsal view of the skull. *b.* Ventral view of the skull. *c.* Ventral view of the vertebral column to the first caudal vertebra, in which the haemal arch is closed *d.* Dorsal view of the caudal vertebrae in which the lateral process or ridge is more or less developed. *e, f, g.* Three stages of the development of the haemal processes in the precaudal vertebrae. In the last stage the epihaemal process is remarkably developed.

PLATE XXXIV.

Fig. 61. *Cybium guttatum.*
Fig. 62. *Grammatorcynus bilineatus.*
Fig. 63. *Rastrelliger chrysozonus.*
Fig. 64. Skull and vertebral column of *Neothunnus rarus.*

a. Dorsal view of the skull. *b.* Ventral of the skull. *c.* Ventral view of the anterior vertebrae till the first haemal arch is closed. *d.* Dorsal view of the caudal vertebrae.

Index to the Vernacular Names.

Index.

Dorsal aorta
Cardinal vein

Ovary

Gall-bladder

Intestine

Scomber japonicus

Cutaneous blood-vessels

Auris mara

Hypaxial tendon attached
to the tail

Dorsal aorta   Cardinal vein

S. Kikkawa del.

1

Pylorie cœcon

Tendon attached to the second vertebra

Tendon attached to the supraclavicle

2

Hepatic vein　　　Pyloric cœca

Dorsal | branches of cu
Ventral | blood-ves:
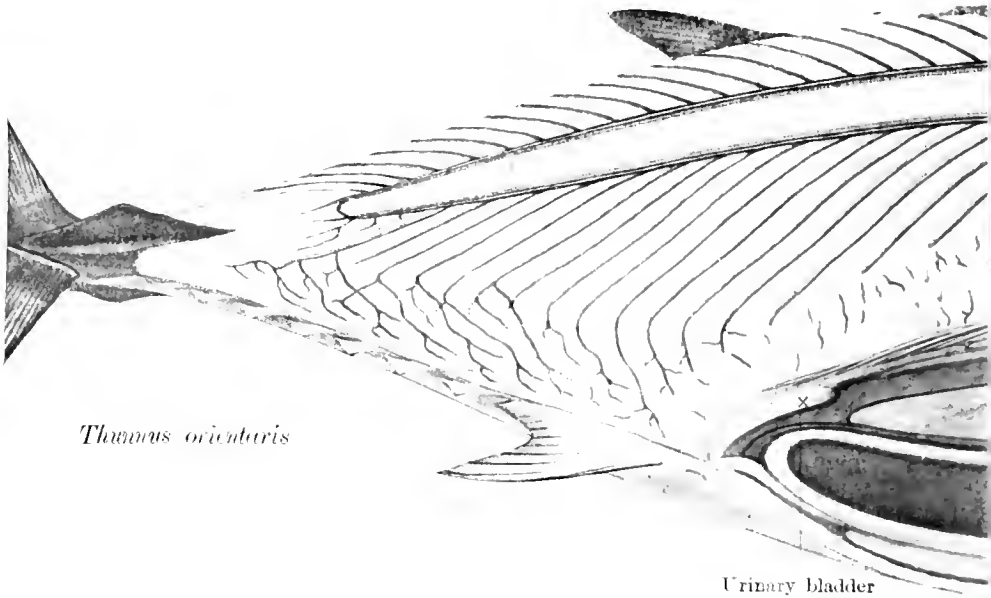
Thunnus orientalis

Urinary bladder

Dorsal branches of the cutaneous
blood-vessels

Transverse commissure of the
cutaneous blood-vessels
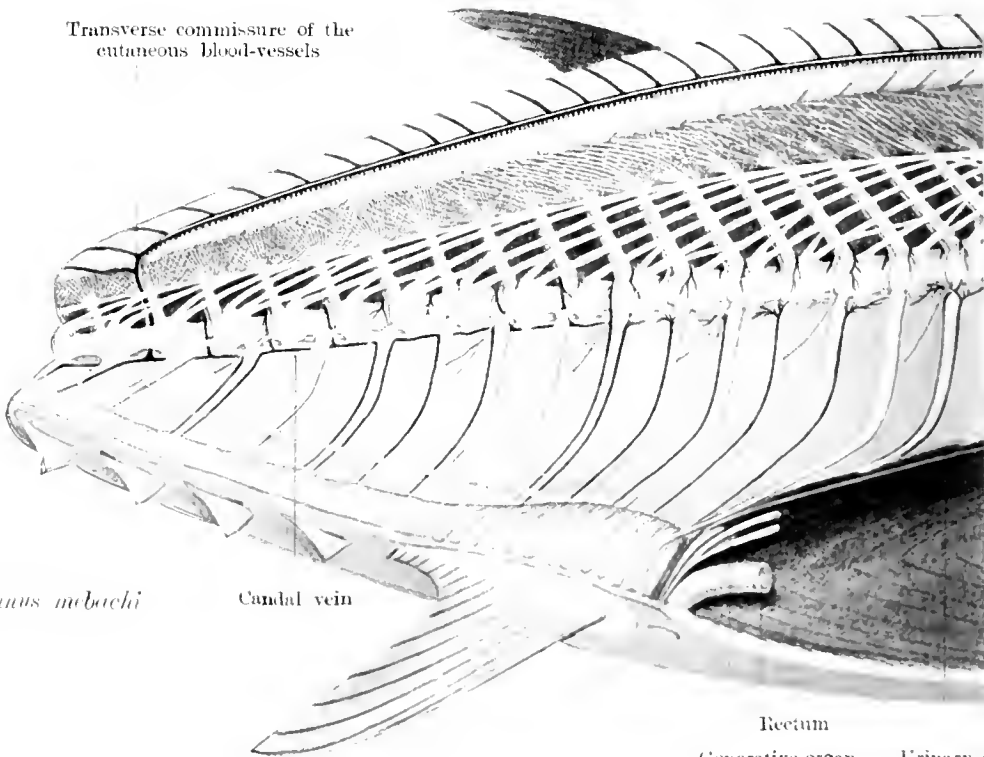
Parathunnus mebachi

Caudal vein

Rectum

Generative organ   Urinary

Pl. XIV.

eous

Intermuscular bones

Kidney

3

Stomach

Liver

Spleen

Pyloric coeca

Air-bladder

Dorsal aorta

4

Kidney

Pharyngeal muscle

Lateral vein

Dorsal cutaneous
blood-vessels

Vas

Katsuwonus pelamis

Cardinal vein

Myocommata

Ovary

Stomach

Pylor

Cybium niphonium

S. Kikkawa del.
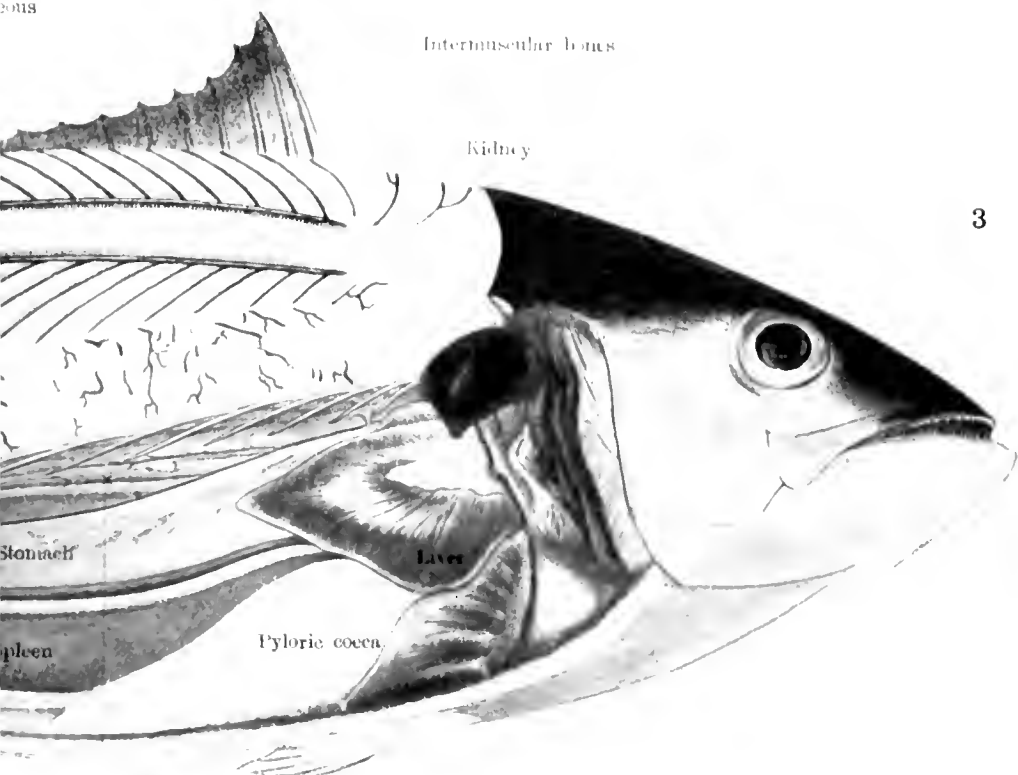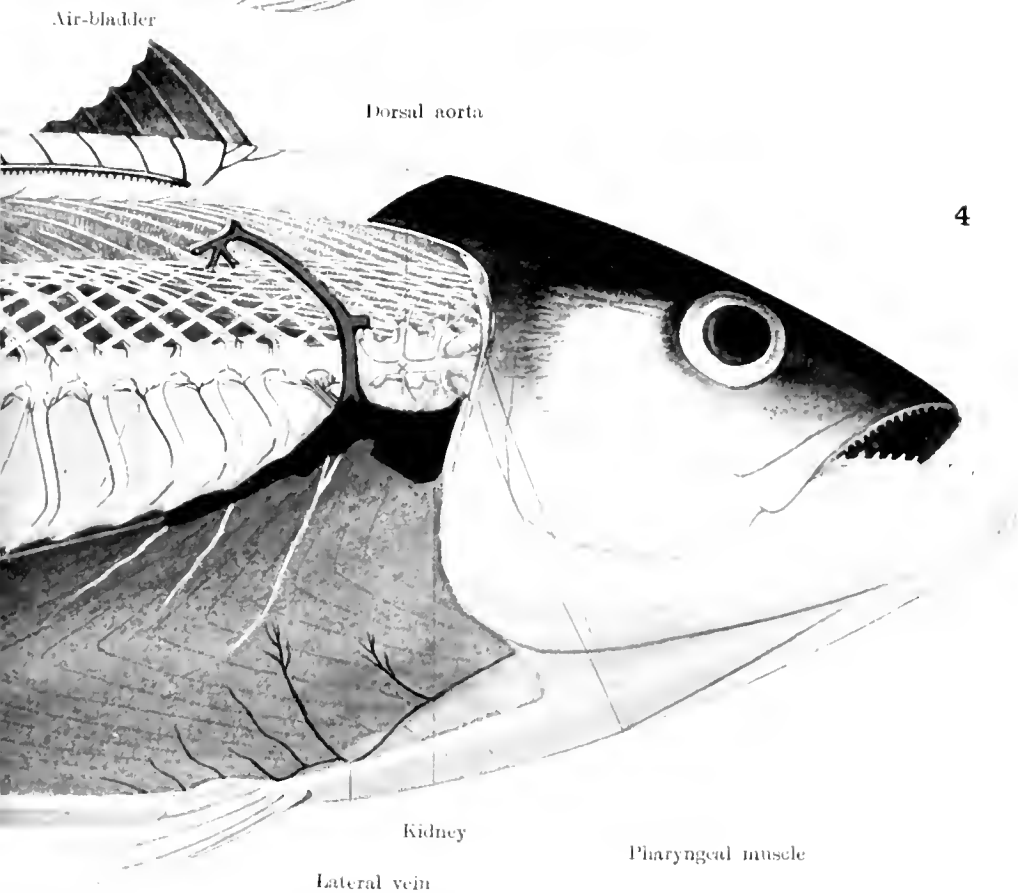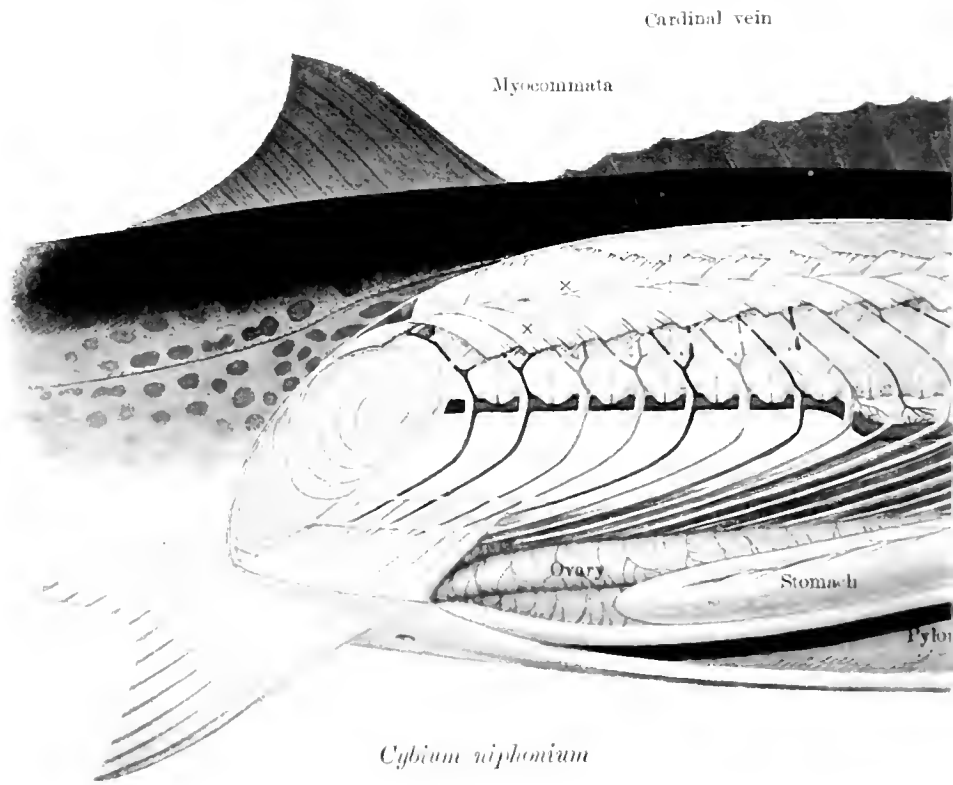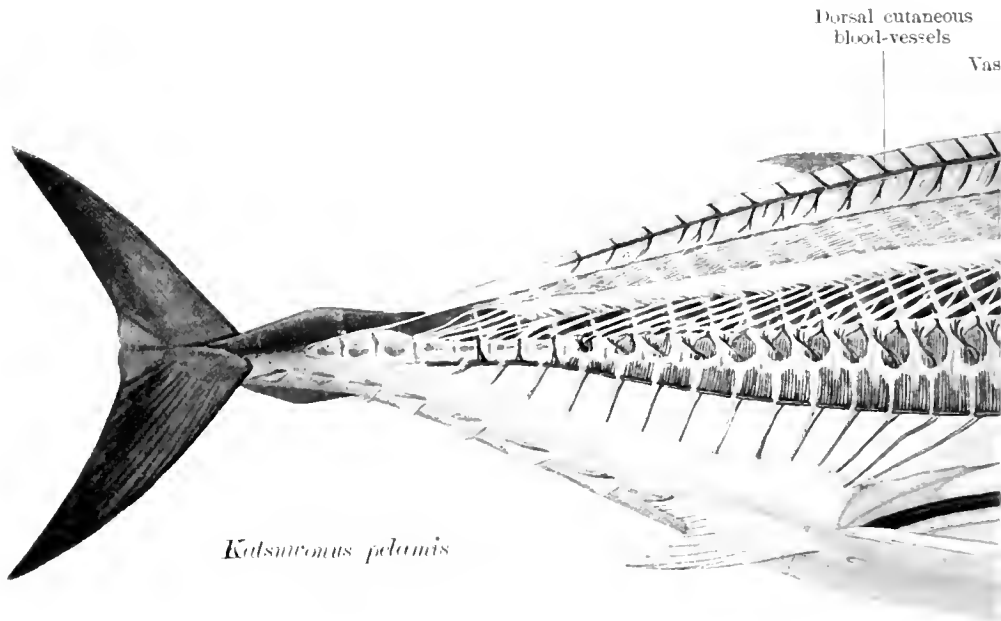
plexus
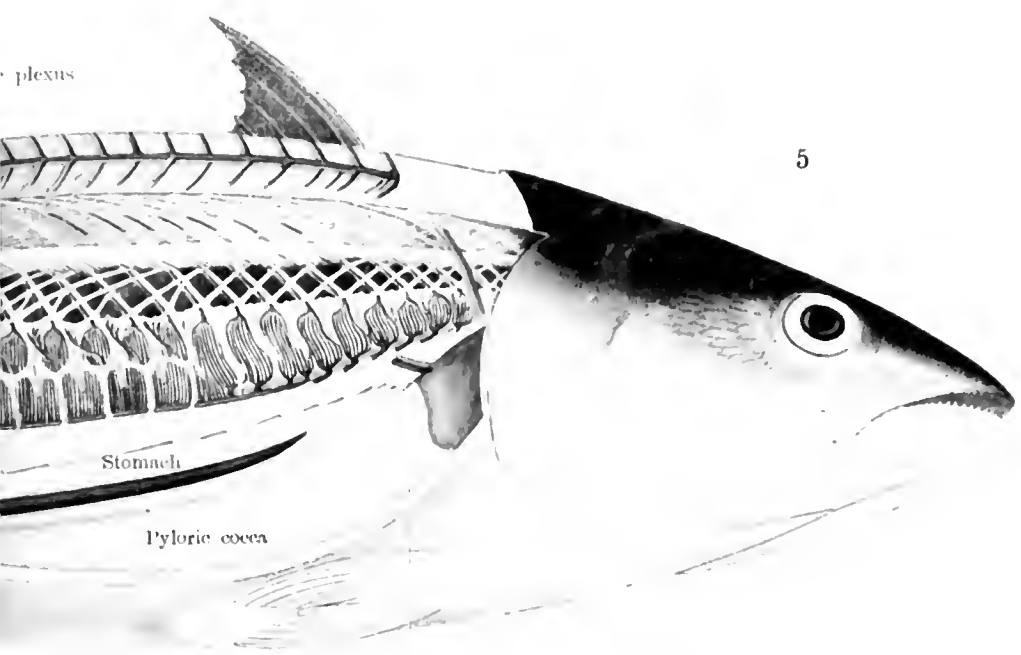
5

Stomach

Pyloric cocca

Ventral cutaneous blood-vessels

6
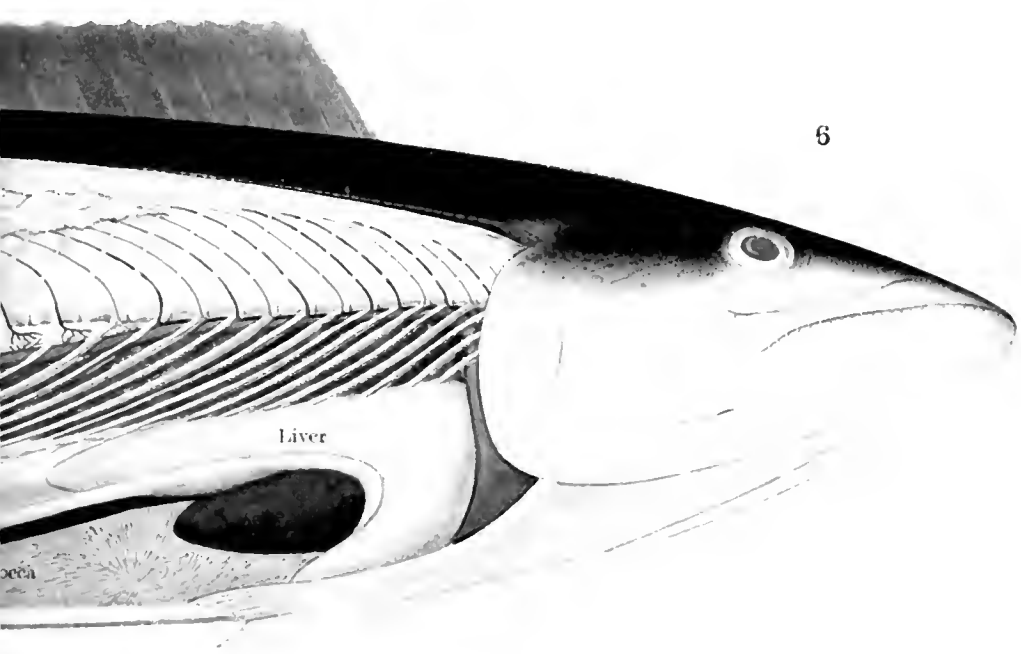
Liver

occa

Renal portal vein
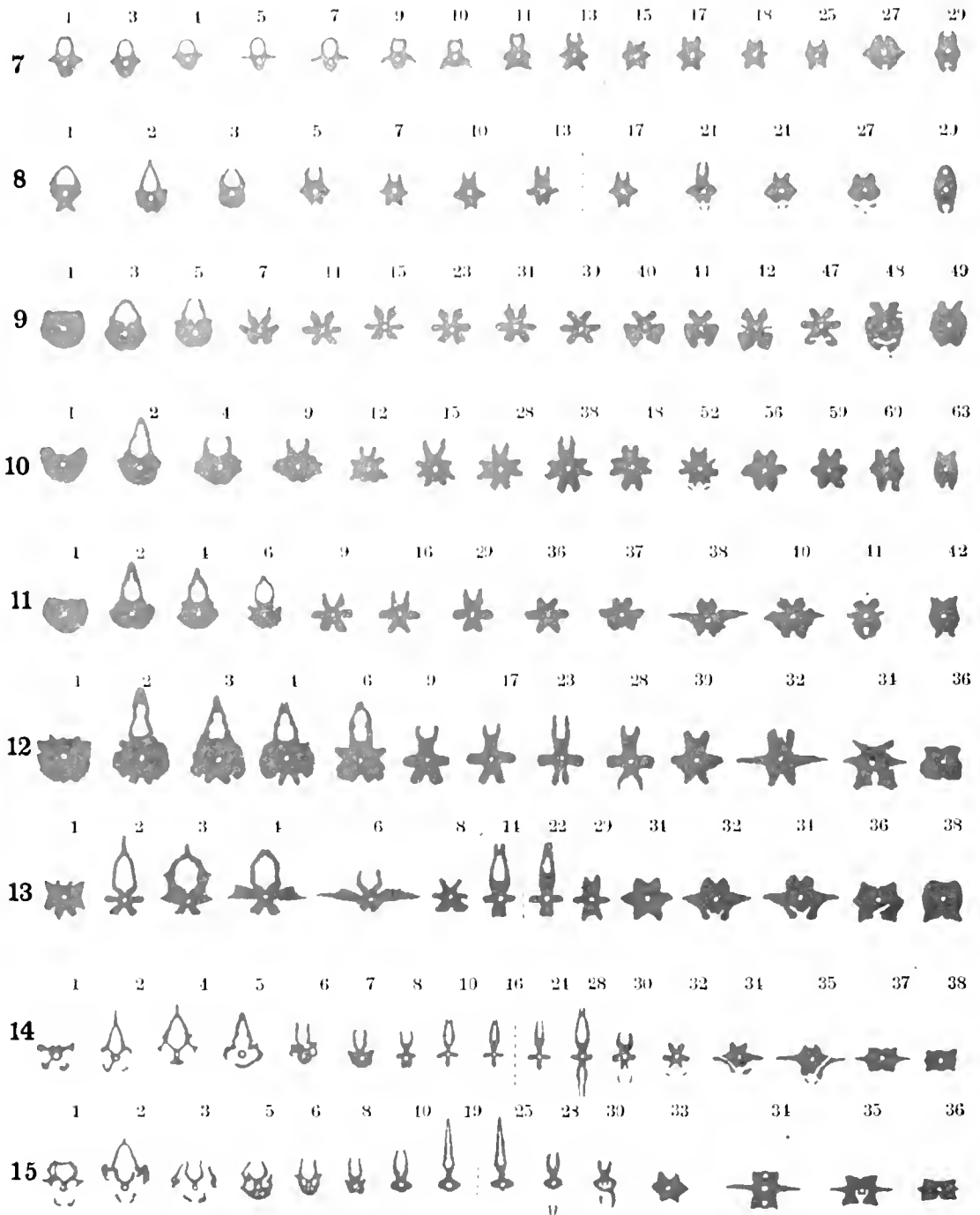
Middle Transverse Section of Vertebrae.

7. *Scomber japonicus* (14 + 17).	8. *Grammatorcynus bilineatus* (13 + 18).
9. *Cybium niphonium* (22 + 28).	10. *Acanthocybium solandri* (33 + 31).
11. *Sarda orientalis* (25 + 20).	12. *Gymnosarda nuda* (19 + 19).
13. *Neothunnus macropterus* (18 + 21).	14. *Katsuwonus pelamis* (20 + 21).
15. *Auxis maru* (20 + 19).	

A dotted line separates the caudal vertebrae from the precaudal, and the numerals in a smaller type denote the ordinal number of vertebrae, counted from the anterior end.

16

17
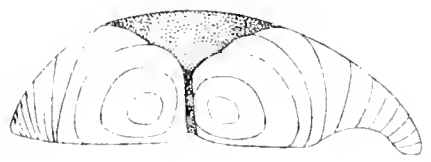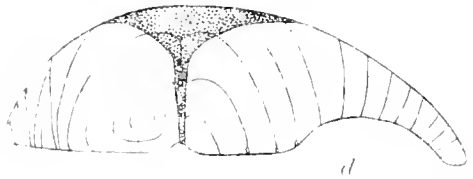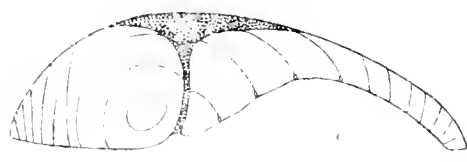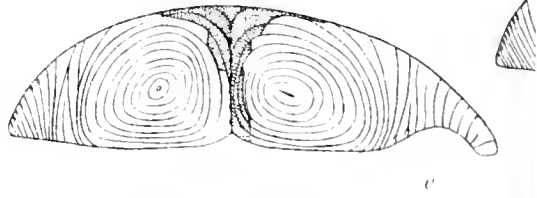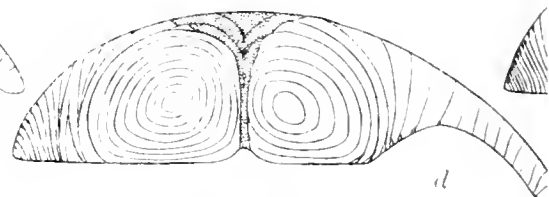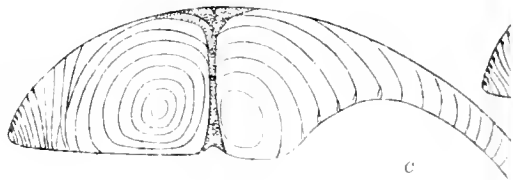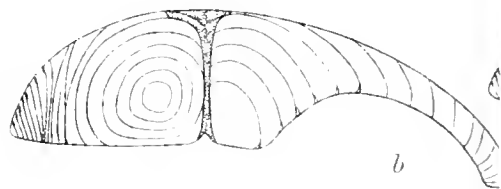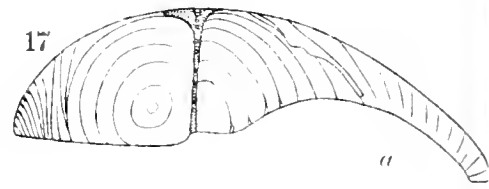
Scomber japonicus   *Sarda orientalis*

Cross-sections of the lateral muscle and the dorsal and
dark coloured portion and blood
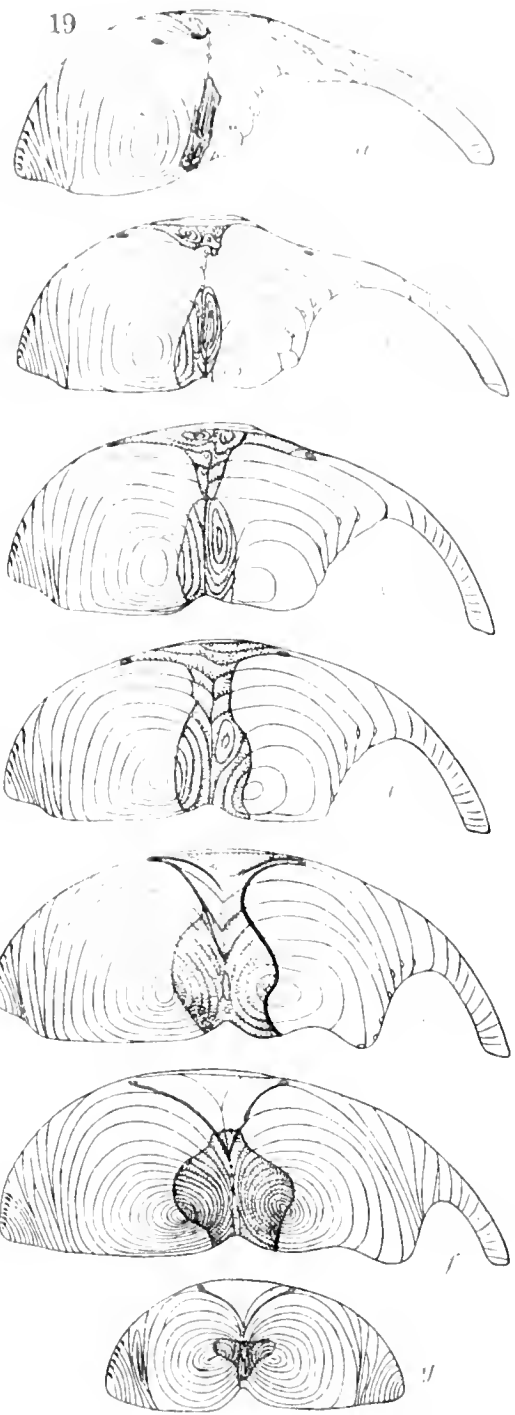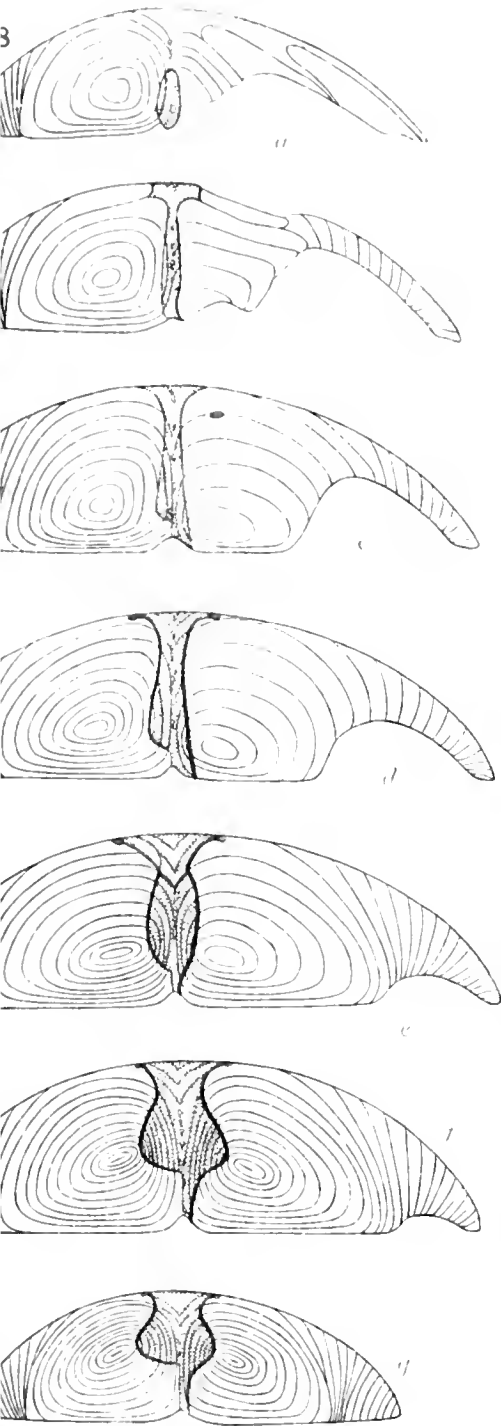
Pl. XVII.

Neothunnus macropterus

Katsuwonus pelamis

tral carinales (one half moiety), showing the relation between the
ssels, and also the number of myotomoes.

20

Thunnus germo.

26

Euthynnus yito.

21

Thunnus orientalis.

23
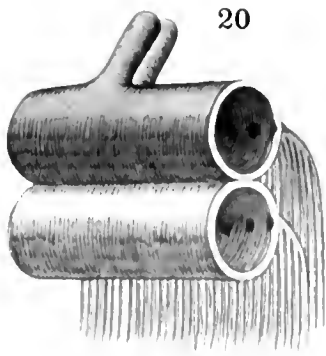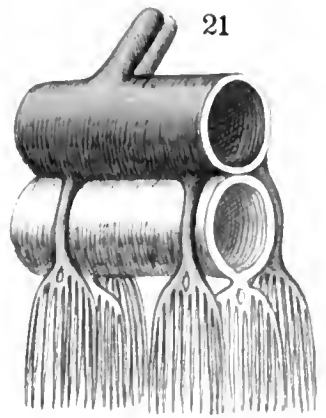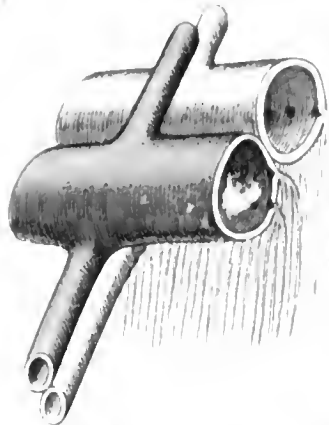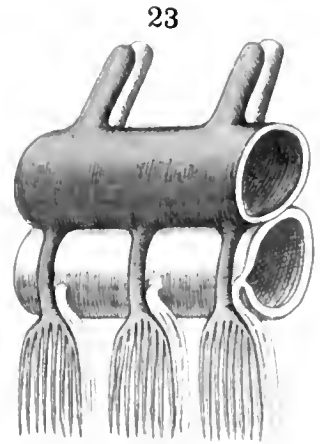
Neothunnus macropterus.

22

Parathunnus mebachi.

27

Auxis maru.

24
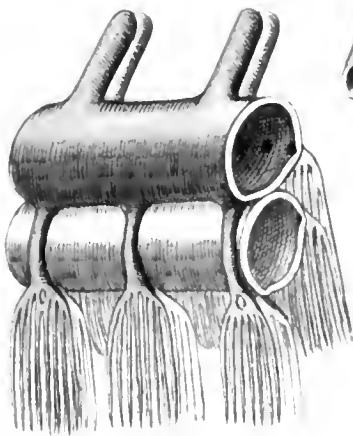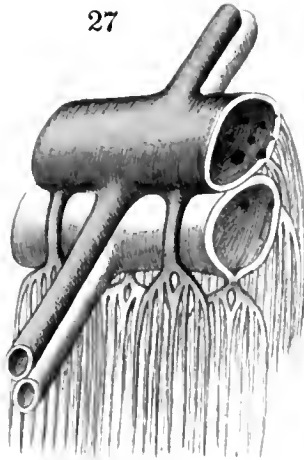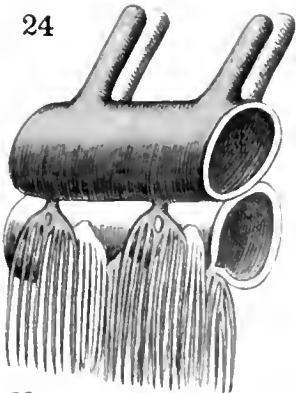
Neothunnus rarus.

25

Katsuwonus pelamis.
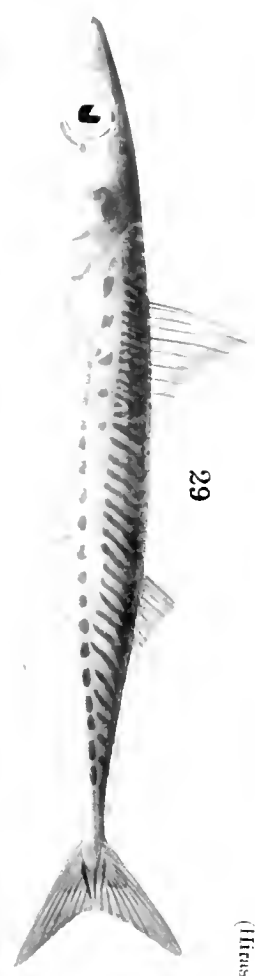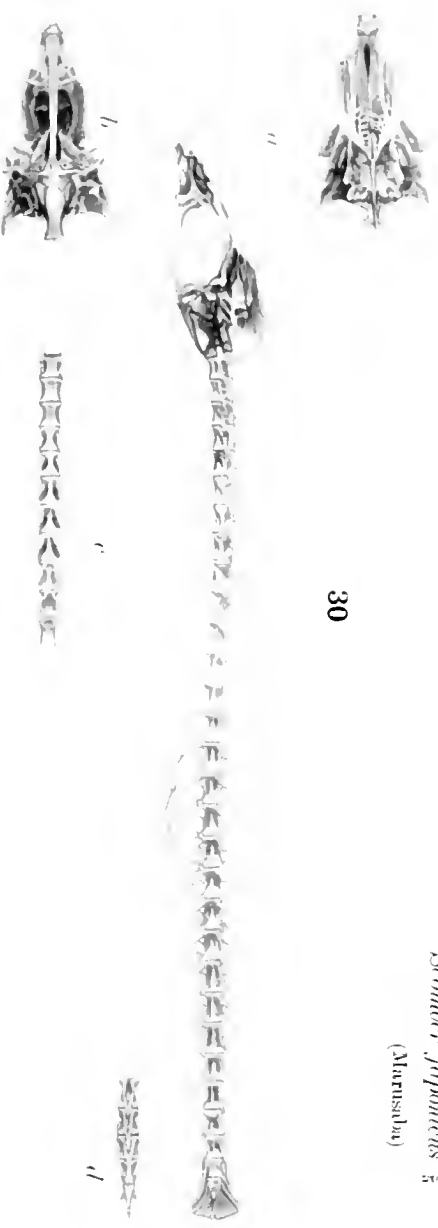
Cutaneous blood-vessels (expaxial) and vascular plexus connected with them. Magnified.

30

29

28

Scomber japonicus
(Marusaba)

Scomber japonicus
(Hirasaba)

31

32

Cybium niphonium ¼

33

S. Kikkawa del.

Pl. XX.

Acanthocybium solandri ¼
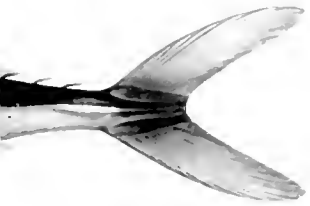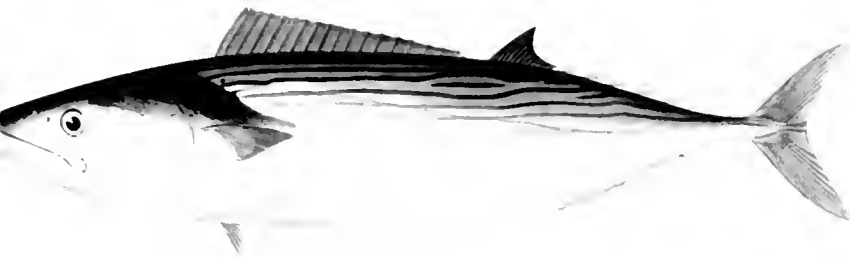
Sarda orientalis ¼

34

35

a

b

S. Kikkawa del.

Pl. XXI.

Cybium chinense ⅟

Cybium koreanum ½ ¼

c

36

37

a　38

b

c

S. Kikkawa del.

Pl. XXII.
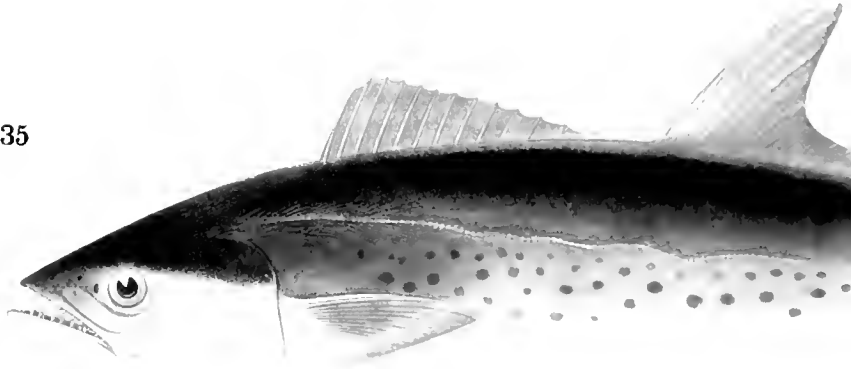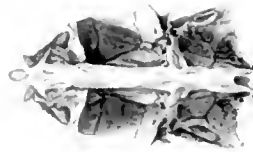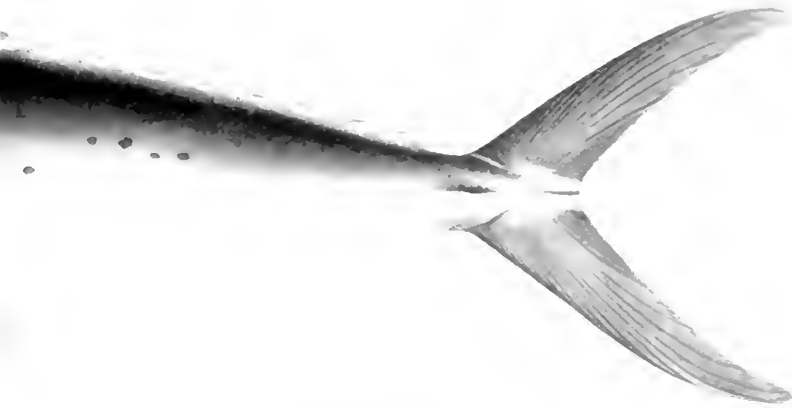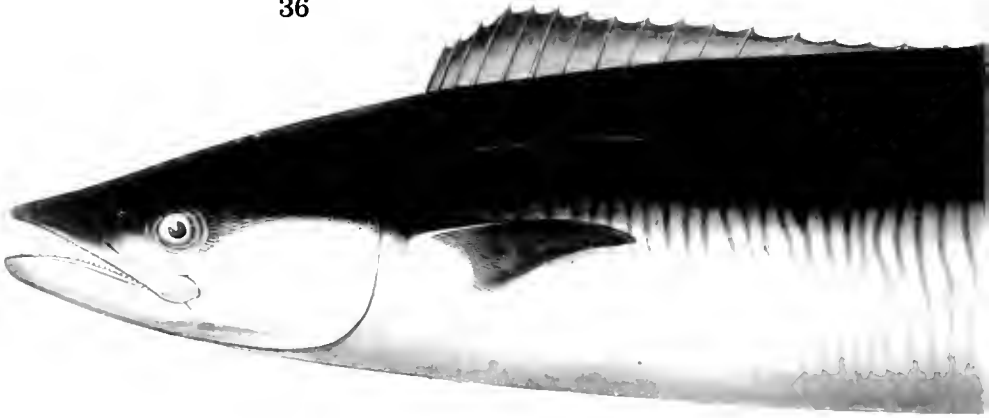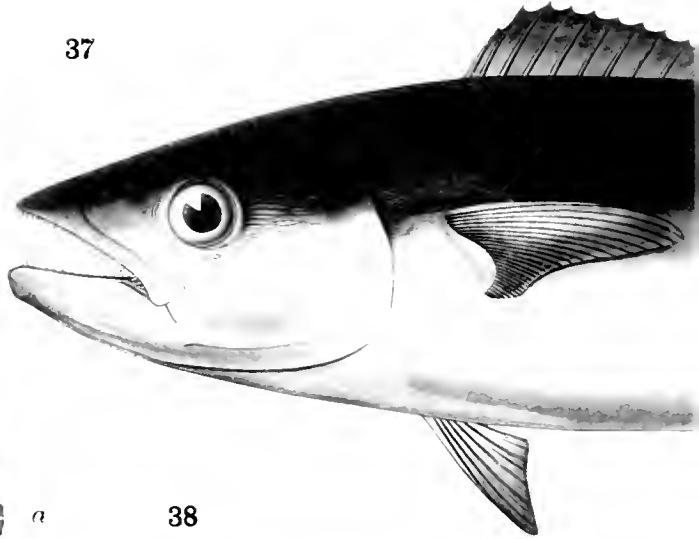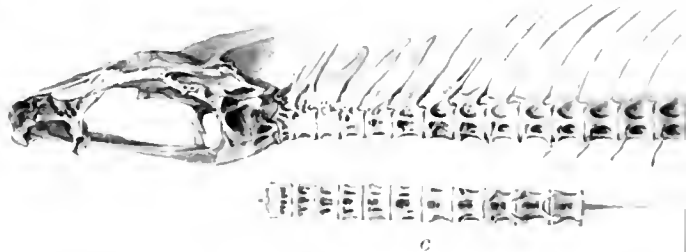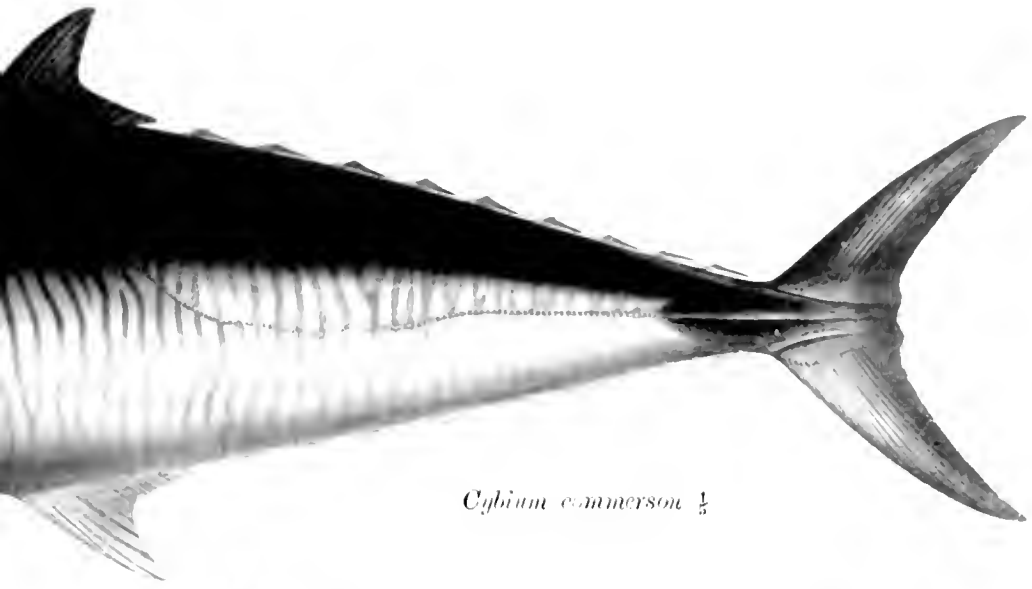
Cybium commerson ½
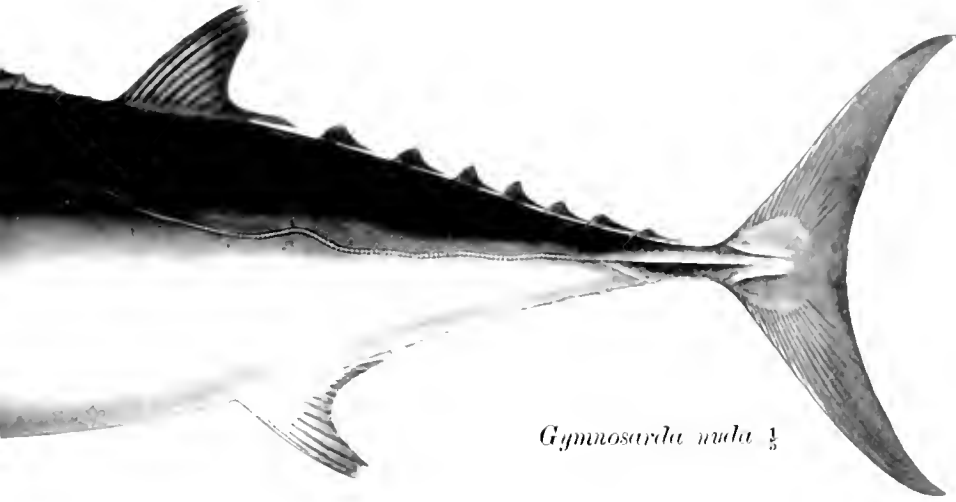
Gymnosarda nuda ½

d

Gymnosarda nuda ½

39

a

c

b

40

a

b

S. Kikkawa del.

Pl. XXIII.

Acanthocybium solandri

Cybium chinense

Sarda orientalis

Cybium niphonium

42

41

44

Thunnus orientalis
(immature)

43
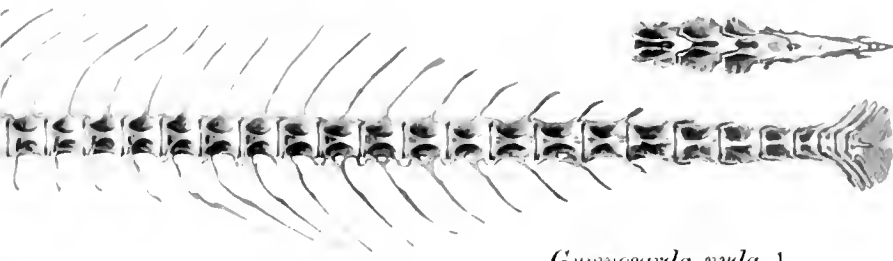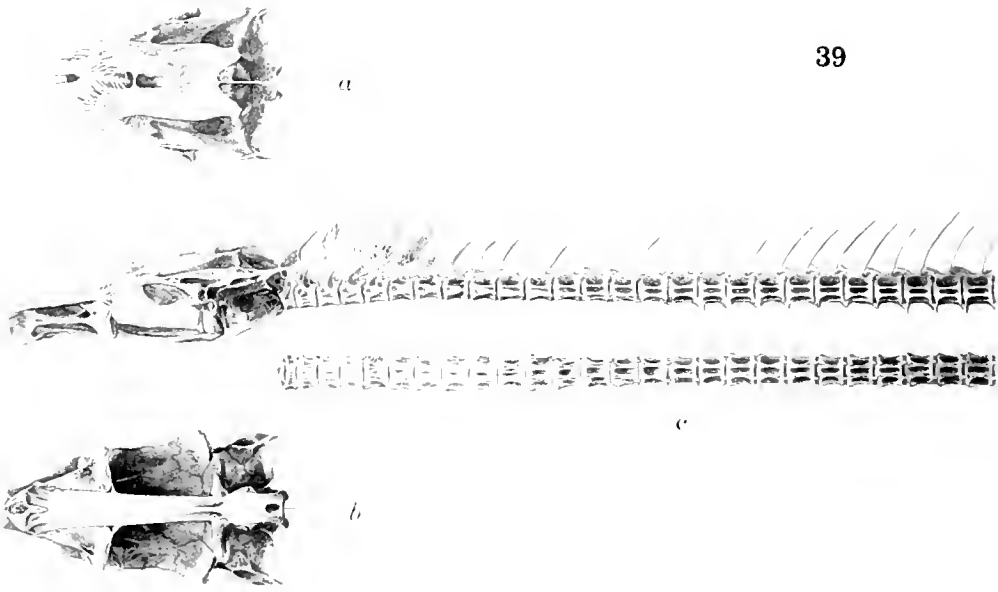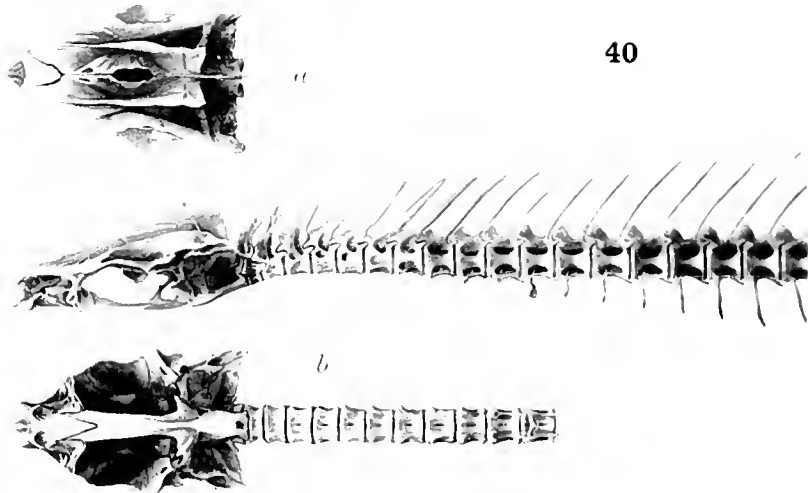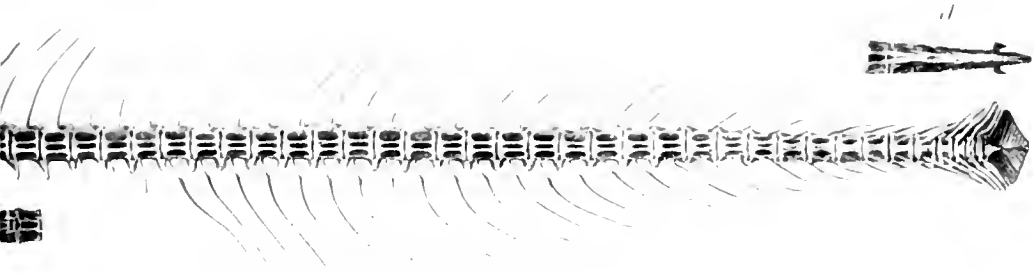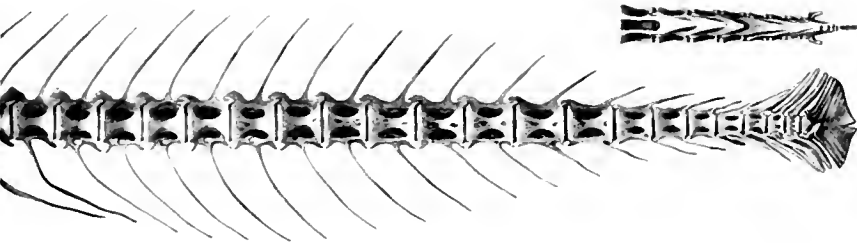
Thunnus orientalis
(immature)

45

46
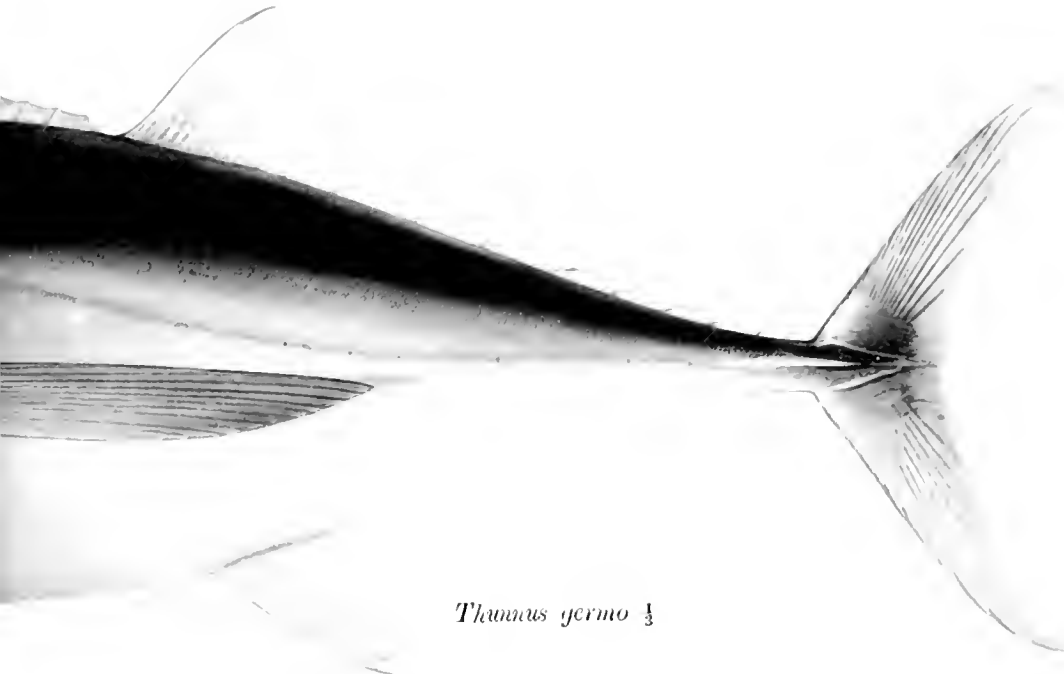
S. Kikkawa del.

Pl. XXVI

Neothunnus macropterus ⅓
(immature)

Thunnus germo ⅓

.

47

48

Pl. XXVII.
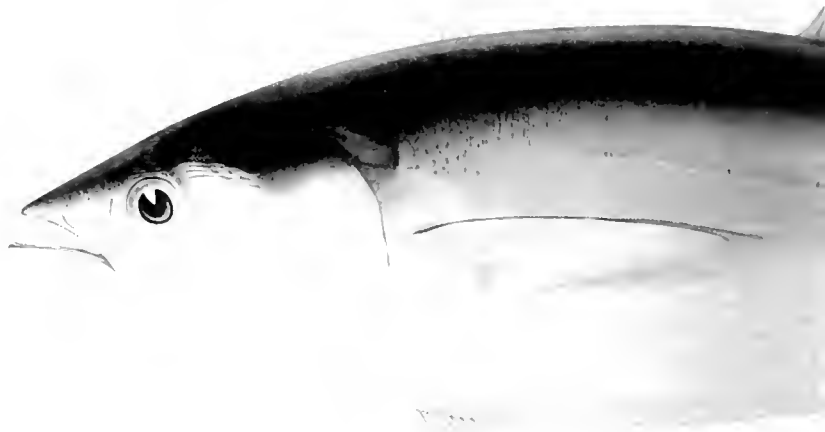
Parathunnus mebachi ⅓
(immature)
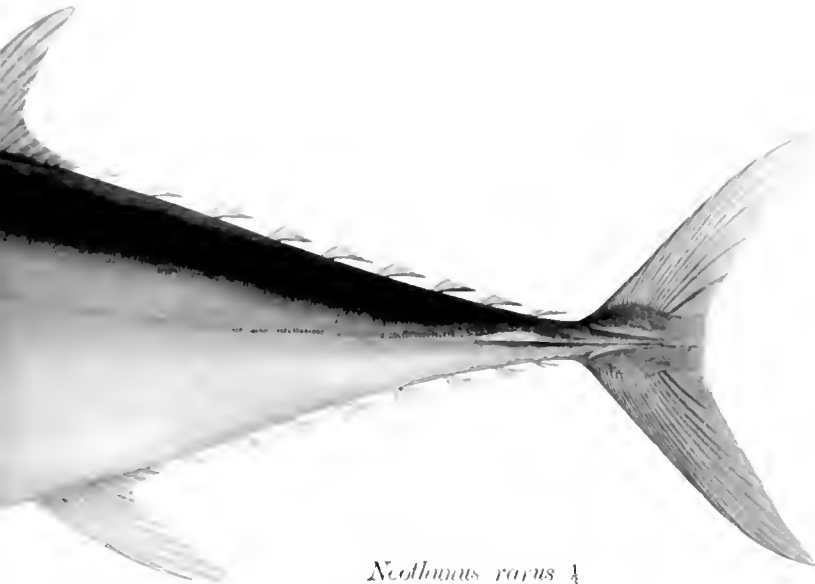
Neothunnus rarus ¼

49

50

S. Kikkawa del.

50 *a*

50 *b*

Pl. XXVIII.
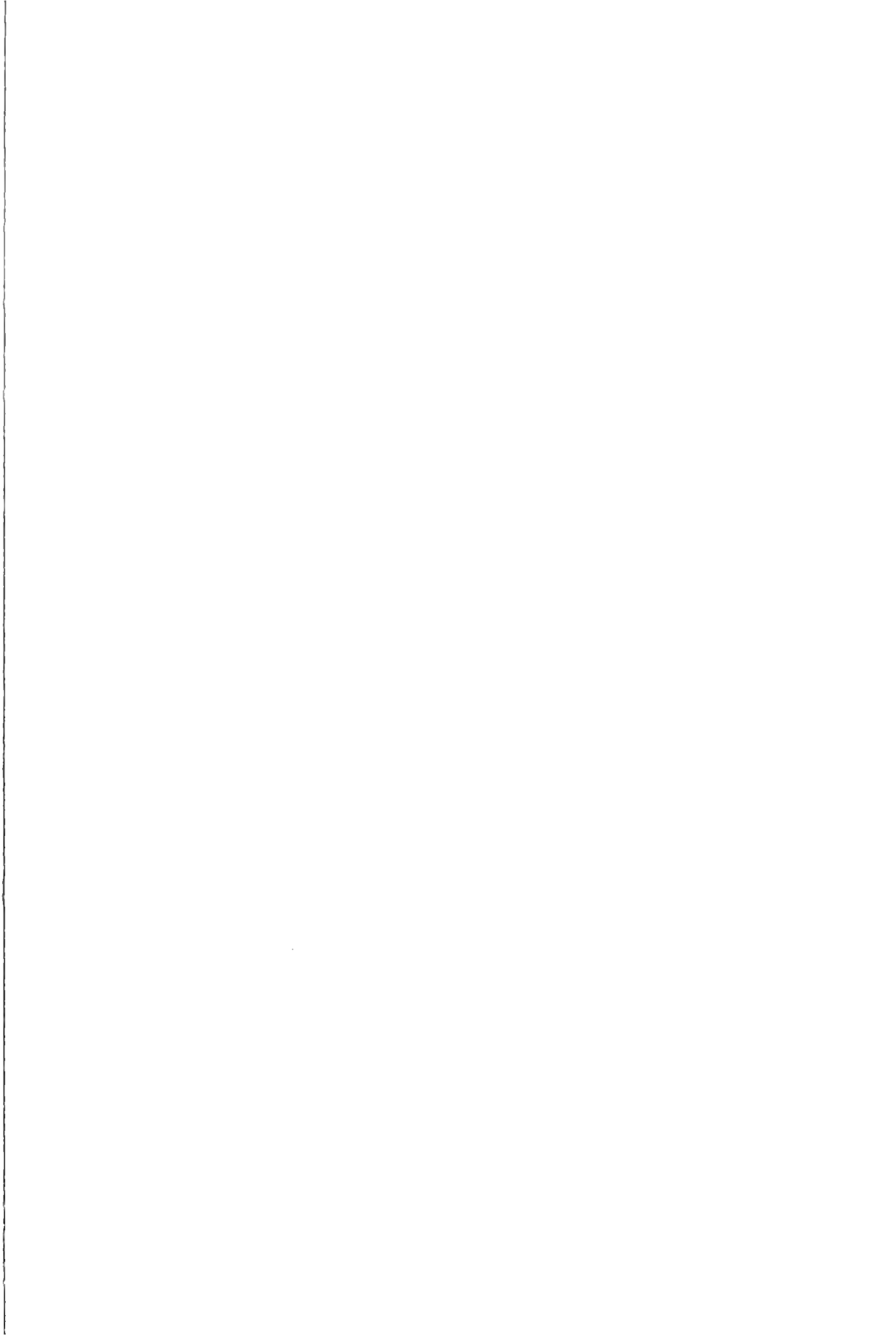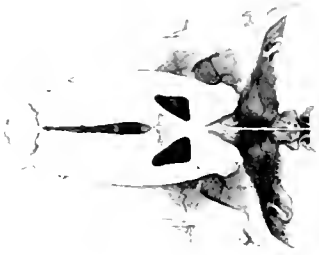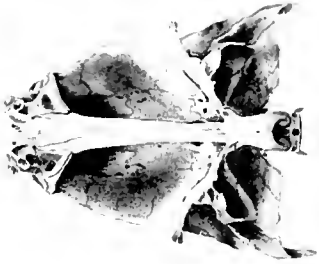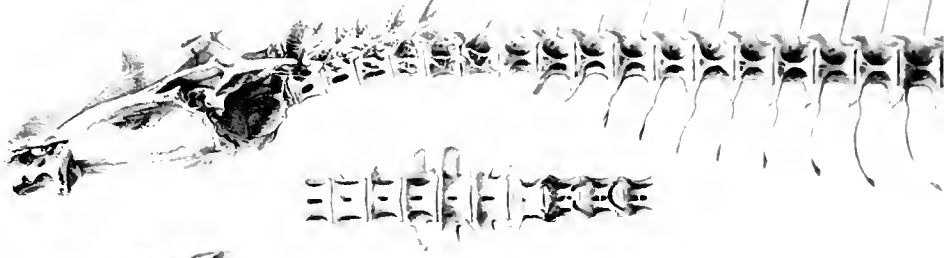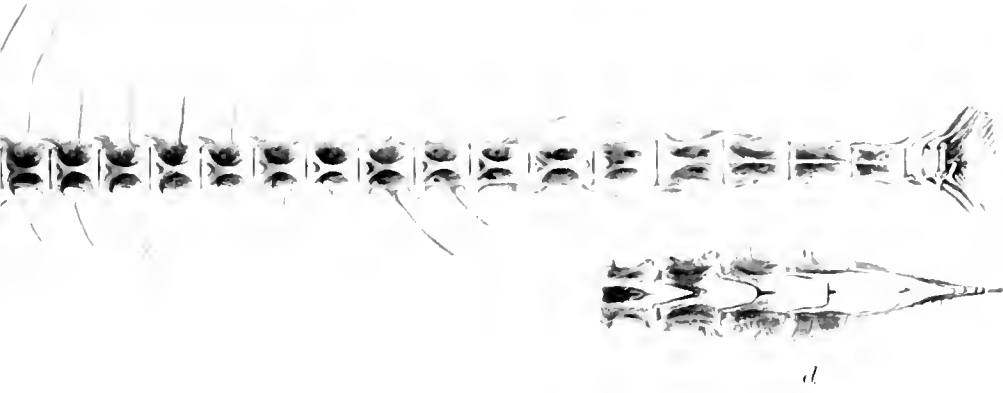
Parathunnus metachi ¼

d

Thunnus orientalis ¼

d

49 *a*

49 *b*

a

c

b

Neothu

a

c

b

Pl. XXIX.

51

d

...acropterus

52

d

Thunnus germo

Pl. XXX.

54

53

Euthynnus yaito ⅓

Katsuwonus pelamis ⅝

S. Kikkawa del.

Pl. XXXI.

56

55

Auxis maru ♀

Auxis hira ♀

S. Kikkawa del.

Euthynnus pelamys $\frac{10}{25}$

Katsuwonus pelamis $\frac{10}{25}$

58

57

Pl. XXXIII.

61

62

Grammatorcynus bilineatus $\frac{10}{23}$

a

64

c

N

b

S. Kikkawa del.

Pl. XXXIV.

Cybium guttatum $\frac{5}{r}$
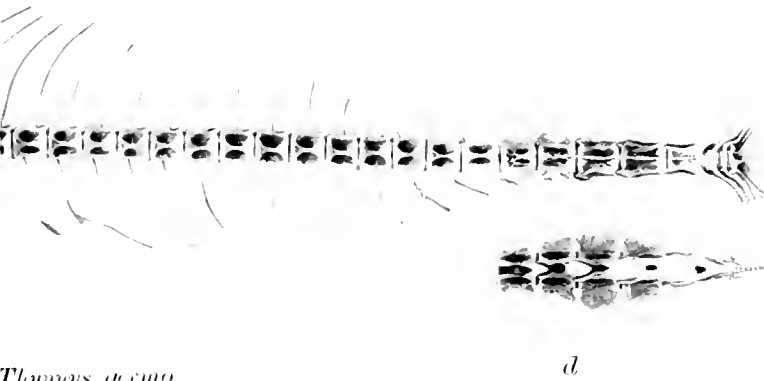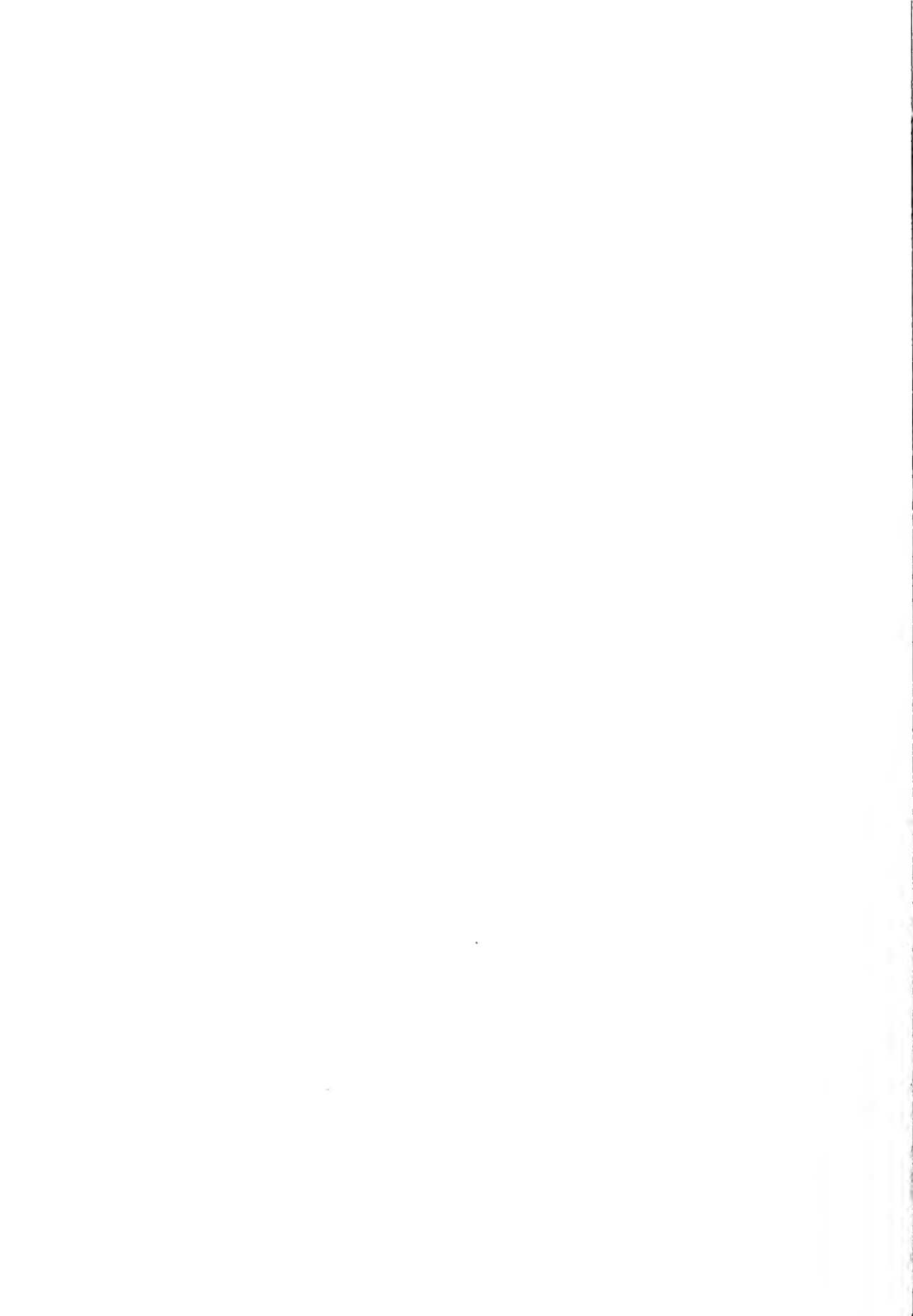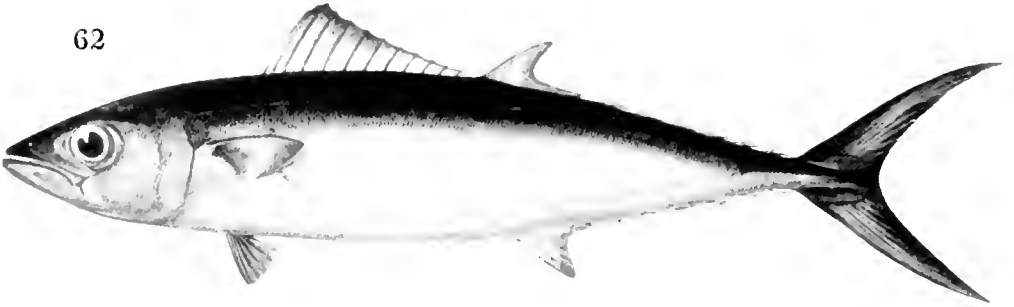
63

Rastelliger chrysozonus $\frac{19}{23}$

...iunnus rarus

d

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